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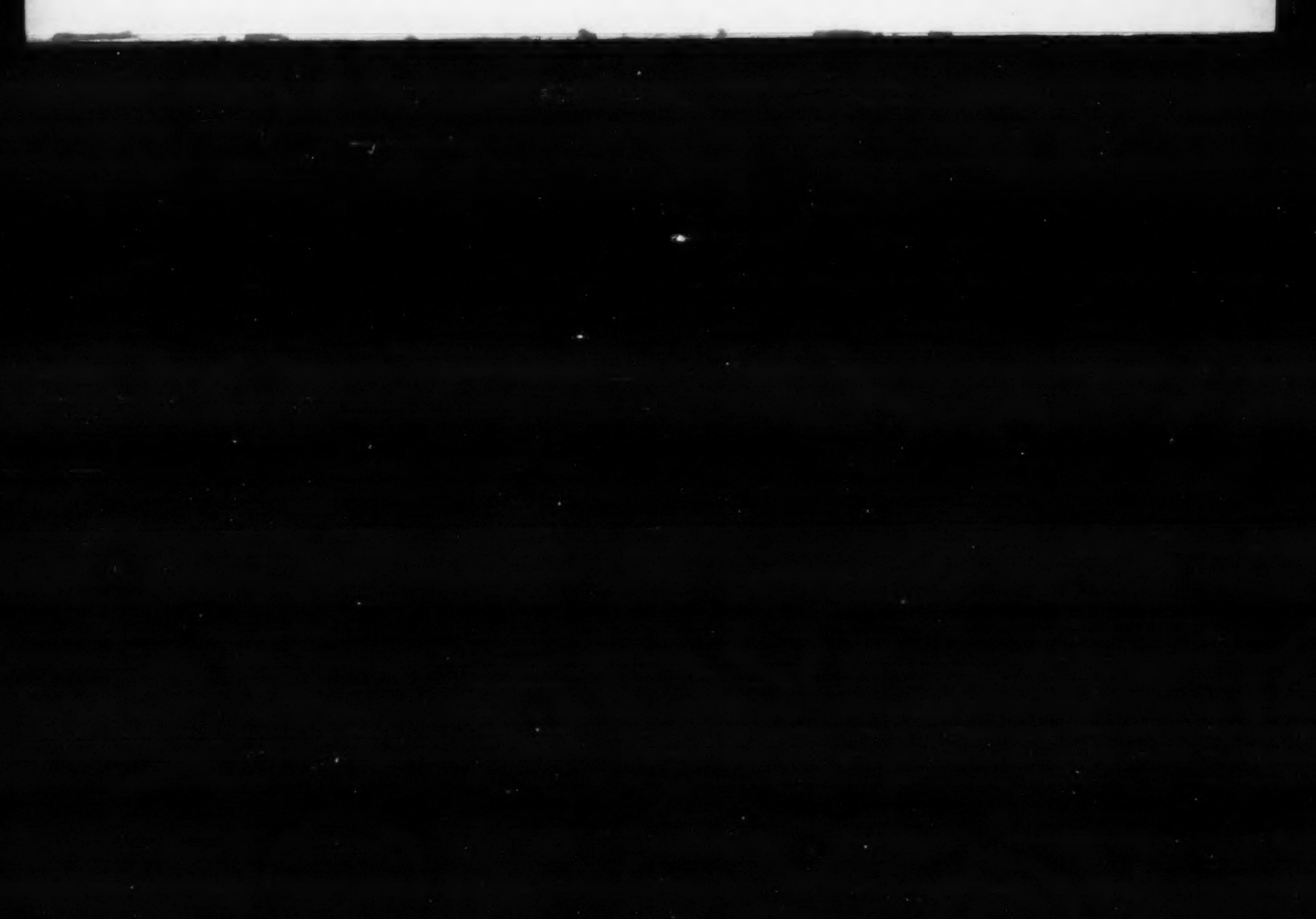

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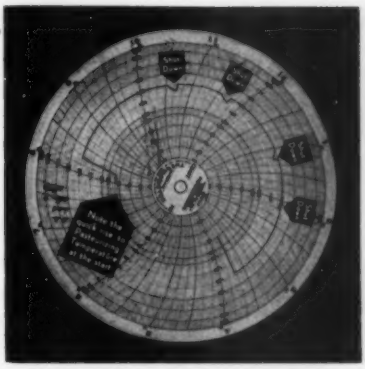

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The American Dairy Science Association was organized to advance the general welfare of the dairy industry, especially by the improvement of dairy instruction by the stimulation of scientific research in all phases of the subject and by improvement in methods of conducting extension work.

Membership shall consist of two kinds: (1) active, (2) associate.

The qualifications for membership in the two classes are as follows: (a) Any person is eligible to active membership who is formally announced by an Agricultural College, or Experiment Station, or by the Bureau of Dairying of the United States Department of Agriculture as an instructor, extension worker, investigator, or administrative officer connected with the dairy industry, or (b) anyone filling a position of responsibility connected with the dairy industry and who has had a college or University training in technical science, or anyone filling a responsible position in the industry of a professional character requiring a technical knowledge of dairying of a high order.

Any person is eligible to associate membership who is regularly enrolled in a collegiate course in a college of Agriculture and who is specializing in dairying. Associate membership is attained by election to membership in a local chapter of the American Dairy Science Association.

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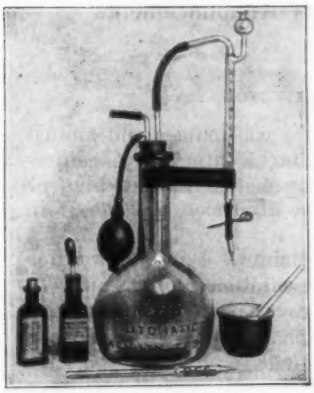

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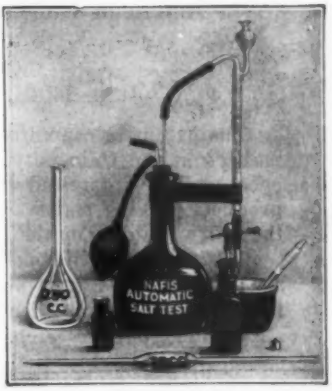

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American Dairy Science Association Announcements

SUMMER MEETING

JUNE 28, 29, AND 30, 1932 AT LEXINGTON, KY.

The executive committee decided to hold the next summer and annual meeting at the University of Kentucky, Lexington, Kentucky. A conference of those interested in judging dairy products and the coaching of products judging teams may be arranged for the afternoon of June 27 in the Dairy Building on the University campus.

The program will consist of short papers, 15 minutes being allowed for each speaker and it is suggested that the presentation require only 10 minutes to allow time for discussion. Papers cover new unpublished research, and new research, teaching, or extension methods. The various sections of the Association will hold special meetings.

Lexington may be reached by automobile on several Federal highways or by the Southern, Louisville and Nashville, or Chesapeake and Ohio Railroads. Reservations should be made at the LaFayette or Phoenix Hotel where special rates have been given to members; hence reservations should be made mentioning the Association.

More information regarding the meeting and scenic points of interest will be given in the next number of the Journal or it may be secured through the program committee consisting of Fordyce Ely of Lexington, chairman, M. Mortensen, and C. L. Roadhouse.

New Officers

The Association elected E. L. Anthony, in charge of the Department of Dairy Husbandry at Michigan State College, as President for the current year, and R. B. Stoltz, in charge of the Department of Dairy Technology at Ohio State University as Vice President. Other changes in officers of the Sections and Divisions as reported to the Secretary-Treasurer or Editor will be found on the directory page.

Constitutional Amendments

Article 6, paragraph 1 of the constitution was amended by ballot so that the President and Vice President are now elected for a term of one year beginning October 1. The ballots shall be mailed to members on or before August 20, according to the change in by-laws. These two changes in the time of election of officers and their tenure of office were made to adjust activities to the time of the annual meeting. Formerly, the annual meeting was held in October at the Dairy Industries Exposition but it is now held the last week in June. The change in date of taking office was made to adapt the schedule to the summer meeting.

An Enlarged Journal

The Journal of Dairy Science began the present volume on an enlarged basis. It will publish about 20 per cent additional manuscript pages this year and each number will contain one or two additional articles as in the January and the present issues.

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A STUDY OF THE GESTATION PERIOD OF HOLSTEIN-FRIESIAN COWS[1]

J. C. KNOTT

Division of Dairy Husbandry, Agricultural Experiment Station, State College of Washington, Pullman, Washington

Investigators have made occasional studies of the duration of gestation of cattle for over a century. Most of these studies have been made with a relatively small number of animals and because of the extreme variation found by some of the earlier investigators, it seems quite probable that some of the records to which they had access may not have been as accurate as could be desired. Those who have studied this subject more recently have, in general, found less variation and have arrived at conclusions that are more uniform.

The length of the gestation period has interested stockmen for many years, because a knowledge of the time to expect the birth of the calf enables proper preparation, such as drying off the cow and getting her in the proper physical condition for parturition and subsequent lactation.

The duration of gestation may be, to some extent, an index of the sexual health of the breeding herd. It is believed by many stockmen that any calf that is born following a gestation considerably shorter than the average is not liable to develop into an animal of superior merit.

Early investigators (1), (2), (3), (4) observed gestation periods varying from 210 to 353 days with averages ranging from 280 to 288 days. It is difficult to understand how periods varying as much as 50 per cent of the mean could be normal, although the upper and lower limits of normal gestations have not been definitely established. Many stockmen question the normality of gestation periods shorter than 270 days and it is quite possible that many reported periods exceeding 290 days may be the result of later services that were not recorded.

Williams (5) has given 285 days as the standard with a normal variation of five days above or below that figure. No authority is given for his assumption that 285 days is the ideal length of gestation in the cow.

Wing (6) reports on his observation of 194 gestation periods in the Cornell University herd. The shortest gestation period observed by Wing was 264 days and the longest 296 days with an average of 280 days regardless of the sex of the offspring. The gestation periods where twins were born averaged five days less than the general average and eight days less than the average of the single births of the same cows.

Received for publication June 4, 1931.

[1] Published as scientific Paper No. 191, College of Agriculture and Experiment Station, State College of Washington.

Fleming (7) summarizes 1,062 observations made at the Agricultural School of Saulsaie, and by Blaine, Tessier, Grille, and Furstenberg. Fifteen were pregnant for less than 241 days, 52 from 241 to 270, and 32 beyond 301 days with an average of 283 days.

McCandlish (8) presents data collected from the dairy herd at the Iowa State College. His summary is based on 369 gestation periods with a mean of 280 days. The length of the gestation period was not affected by the sex of the calf, the breed of the cow, age at calving, or season of freshening.

Contrary to McCandlish's findings, Fitch, McGillard and Drumm (9) found a difference in the length of gestation periods between breeds. The average for Jerseys was 284.3 days; for Guernseys 283.0 days; for Ayrshires 284.6 days, and for Holsteins 281.0 days.

Copeland (10) in studying 1,075 cases of Jersey cows found an average length of gestation of 278.5 days. He observed that there was an equal chance of a cow calving any time between the 271st and 285th day. His data showed that the age of the dam had no effect on the length of gestation and that the male calves were carried approximately one day longer than the female calves.

INVESTIGATIONAL

This study was undertaken to determine, insofar as possible with the material available, the average length of the normal gestation period of Holstein-Friesian cattle, the variations that occur, and the causes for such variations. It was believed that data on a large number of gestations might give rather definite information on many points that had been indicated in previous investigations, but had not been substantiated for lack of data on a sufficient number of cases.

The data used were obtained from the herds of the Carnation Milk Farms at Carnation, Washington; the Western State Hospital at Fort Steilacoom, Washington; and the State College of Washington at Pullman, Washington.

Data were obtained on 2,910 gestation periods. Seventy-eight of the animals included were grade Holsteins and 2,832 were pure bred Holsteins. Twins were dropped following 86 of these gestation periods and are considered separately in the presentation of the data.

The term "gestation period" is usually understood to include the time from the effective service of the cow by the bull until the birth of the calf. Mumford (11) gives the following definition:

> "The period of development from the fertilization of the egg by the sperm cell until the birth of the fully developed offspring capable of independent existence outside the body of the mother is known as the period of gestation."

Ovulation and the fertilization of the ovum usually occurs from 30 to 60, or more, hours after the cessation of the mating period. It is not possible to use Mumford's definition of the gestation period in this work, because it is not known just when fertilization of the ovum takes place in each pregnancy.

The term "gestation period," as used in this paper, includes the period from the time of service to the birth of a living, fully developed calf including both the day that the cow was bred and the day that the calf was born.

In collecting these data, no gestations that ended in the dropping of a dead calf were included. Whenever a calving was marked as abnormal on the breeding record, the gestation period was excluded. Where the necessary information was available, all gestation periods that were terminated by the birth of a living calf were included.

The average length of the 2,824 gestation periods studied that terminated with single births was 279.9 ± 0.063.

Table 1 shows the distribution of the cases included in this investigation.

Table 1. Distribution and Frequency of Gestation Periods

| Parity | Sex | Cases in Gestation Period | | |

The distribution on each side of the mean is quite uniform, as we find that there are 1,296 cases, or 45.9 per cent, that were carried for 281 days or longer and 1,322 cases, or 46.8 per cent, carried for 279 days or less.

Fewer calves were born on the 280th day, which is the mean, than there were on the 279th, 281st, or 282nd days.

One thousand seventy-seven calves, or 38.1 per cent, were dropped during the five days from 278 to 282 inclusive. The period of seven days, which includes three days each side of the mean, or from 277 to 283 days inclusive, includes 1,476, or 52.3 per cent, of the total cases. Two thousand eighty-one cases, or 73.7 per cent, are included in the period from 275 to 285 days inclusive, which includes five days above and below the mean.

The influence of the sex of the calf upon the duration of gestation is a question about which there has been a considerable difference of opinion. Many investigators have found that the average gestation period was the same regardless of the sex of the calf, while others have found that the male calves are on the average carried in dam longer than the females.

The average length of gestation periods in days in the 1,441 cases where males were dropped was 280.4 ± 0.090. One thousand three hundred eighty-three females were dropped following gestation periods that averaged 279.4 ± 0.087. This difference of exactly one day is certainly not large, but statistically significant, as it is eleven times the probable error. A thorough study of the data presented can hardly fail to reveal that there seems to be a well defined tendency for the male calves to be carried longer than the females.

From 271 to 280 days inclusive, 1,438 calves were born, of which 660 were males, while 778 were females. This represents 45.8 per cent of the males and 56.3 per cent of the females. In the group of 1,254 calves born from 281 to 290 days inclusive, 705, or 48.9 per cent, of the males and 549, or 39.7 per cent, of the females were included.

Beginning with the 271st day and up to and including the 280th day, more females than males were born each day. Beginning with the 281st day and up to and including the 295th day, more males than females were born each day with the exception of the 286th day when 58, or 4.2 per cent, of the females and 55, or 3.8 per cent, of the males were dropped.

In figure 1, it will be noticed that the line representing the females quite uniformly goes up one day earlier and down one day earlier than does the line representing the male calves.

In table 2 where the average gestation for the male and the female calves are segregated according to the age of the cow at calving in only two cases is the average gestation period longer for the female calves than for the males. These two cases are with nine-year olds and fourteen-year olds and for the latter there was only a total of seven calves.

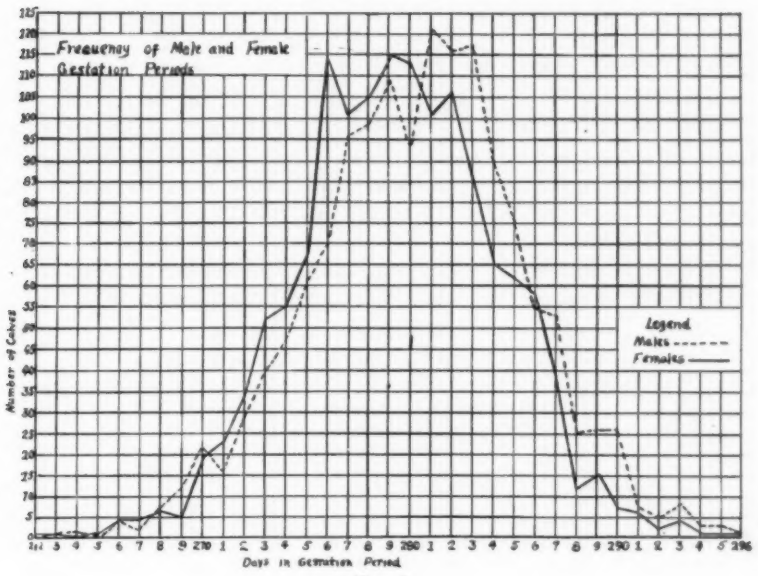

FIG. 1

TABLE 2

Average Length of Gestation Periods

AGE YEARS	NUMBER OF CALVES			AVERAGE LENGTH OF GESTATION		
	Males	Females	Total	Males	Females	Both Sexes
1	12	3	15	279.4	277.3	279.0
2	314	318	632	279.8	278.8	279.3
3	266	240	506	279.6	279.0	279.3
4	197	212	409	280.7	279.2	279.9
5	153	140	293	281.1	279.6	280.4
6	121	119	240	281.0	280.4	280.7
7	103	94	197	280.6	280.5	280.6
8	88	85	173	281.1	279.1	280.1
9	72	56	128	280.0	280.5	280.2
10	53	41	94	280.9	280.0	280.5
11	28	37	65	280.4	279.8	280.1
12	15	24	39	281.3	280.0	280.5
13	11	9	20	281.9	279.8	281.0
14	4	3	7	281.5	283.0	282.1
15	4	2	6	282.0	278.0	280.7
Totals	1,441	1,383	2,824	280.4 ± 0.090	279.4 ± 0.087	279.9 ± 0.063

Eight hundred twenty-five, or 57.3 per cent, of all male calves had a gestation period of 280 days or over, while there were but 677, or 49.0 per cent, of all females that were carried 280 days or more.

In considering the effect of the sex of the calf on the length of the gestation period, it is of interest to note that in studying the gestation period of twin calves, it was found that 24 male and male pairs had an average gestation of 276.5 days. Forty-two male and female pairs had an average gestation of 275.8 days, while 20 female and female pairs had an average gestation of 273.9 days. The number of twin births observed was only 86, but the results as given in table 3 are at least interesting and confirm the conclusion for single births—that males are carried longer than females.

TABLE 3

Distribution of Twin Births and Average Gestation Periods of Twins

GESTATION PERIOD DAYS	MALE AND MALE	MALE AND FEMALE	FEMALE AND FEMALE	TOTAL
265	1	.....	.....	1
267	.....	1	2	3
268	1	2	.....	3
269	.....	2	2	4
270	.....	2	3	5
271	.....	2	2	4
272	3	3	1	7
273	3	2	1	6
274	1	2	1	4
275	1	2	1	4
276	2	5	1	8
277	1	5	1	7
278	2	.....	1	3
279	2	3	.....	5
280	2	6	1	9
281	1	2	.....	3
282	1	.....	1	2
283	2	1	2	5
285	.....	1	.....	1
287	1	1	.....	2
Total	24	42	20	86
Average gestation	276.5 ± 0.687	275.8 ± 0.491	273.9 ± 0.762	275.5 ± 0.361

The average length of gestation periods for all twins was 275.5 days. This is 4.4 days less than the average gestation in the case of single births. The distribution of twin births is shown in table 3.

Table 2 gives the number of calves of each sex and of both sexes and the average gestation period of each sex, and of both sexes at the different ages of the dam. There seems to be a slight increase of approximately one and one-half days in the length of the gestation period from two-year olds to six-year olds.

While this slight increase may not be significant, it is interesting as indicating a possible tendency for the length of the gestation period to increase from the time a cow is a two-year old until she reaches maturity, after which there is a tendency for the length of the period to decrease.

Table 4 gives the number of calves and the average gestation of calves for each of 28 sires.

TABLE 4

Influence of Sire on Gestation Period

SIRE	NUMBER OF CALVES			AVERAGE LENGTH OF GESTATION		
	Male	Female	Total	Male	Female	Both Sexes
A	194	174	368	280.5	280.5	280.5
B	54	59	113	279.1	277.4	278.2
C	70	79	149	281.5	280.1	281.2
D	77	78	155	281.4	279.4	280.4
E	50	71	121	279.3	278.6	278.9
F	44	54	98	280.6	278.1	279.2
G	41	33	74	281.0	279.6	280.4
H	24	24	48	278.2	277.7	277.9
I	28	34	62	278.7	277.9	278.3
J	21	14	35	281.5	279.2	280.6
K	23	10	33	280.4	279.1	280.0
L	9	17	26	280.0	278.3	278.9
M	14	18	32	277.3	277.4	277.4
N	7	7	14	280.7	282.9	281.8
O	16	9	25	278.3	277.0	277.8
P	12	17	29	288.6	284.3	286.1
Q	13	11	24	282.3	282.1	282.2
R	9	8	17	279.0	280.5	279.7
S	14	6	20	280.3	278.2	279.7
T	12	14	26	277.5	276.5	277.0
U	64	66	130	279.5	278.1	278.8
V	38	23	60	279.0	280.3	279.5
W	58	51	109	279.5	279.2	279.4
X	19	23	42	277.2	279.4	278.3
Y	17	15	32	279.5	278.1	278.9
Z	23	10	33	280.9	281.4	281.1
A1	33	28	61	284.5	281.7	283.2
B1	9	17	26	279.7	279.7	279.7

In studying the gestation periods as segregated by sires, there appeared to be some that were quite uniformly high with a few periods that diverged widely. The gestation periods of the calves by some sires were uniformly short with a very few that diverged quite widely. The periods of others were quite uniformly average in length with a few long and a few short, while the calves from other sires seemed to have gestation periods quite uniformly and widely scattered over a considerable range.

TABLE 5

Gestation Periods of Individual Cows

COW NO.	AGE IN YEARS												
	2	3	4	5	6	7	8	9	10	11	12	13	Average
317	272	273	274	274	276	.....	280	.....	.....	.....	.....	.....	274.8
391	.....	277	.....	276	279	276	267	279	.....	.....	.....	.....	275.7
733	276	273	279	277	278	275	279	271	278	.....	.....	.....	276.2
2204	.....	.....	278	.....	271	276	282	.....	272	279	.....	.....	276.3
2211	.....	.....	.....	.....	278	280	277	.....	276	272	276	.....	276.5
365	.....	279	272	274	277	276	282	.....	.....	.....	.....	.....	276.7
409	.....	271	273	270	279	279	290	.....	.....	.....	.....	.....	277.0
403	272	278	268	276	278	275	283	.....	.....	287	.....	.....	277.1
715	.....	283	270	279	277	274	282	.....	.....	.....	.....	.....	277.5
2213	.....	280	.....	274	282	283	276	274	.....	275	.....	.....	277.7
2114	277	281	281	.....	278	283	271	.....	.....	.....	.....	.....	278.5
248	.....	.....	.....	277	.....	.....	280	286	272	279	277	281	278.9
2084	.....	280	278	.....	277	276	288	275	.....	.....	.....	.....	279.0
2603	284	287	280	276	276	273	.....	.....	.....	.....	.....	.....	279.3
974	276	.....	282	279	284	.....	283	273	.....	.....	.....	.....	279.5
67B	280	.....	279	287	.....	278	287	277	274	.....	.....	.....	279.9
642	.....	.....	.....	273	281	282	279	284	278	.—	282	.....	279.9
2027	.....	281	276	282	282	.....	272	289	.....	.....	.....	.....	280.3
708	284	284	280	273	280	283	.....	.....	.....	.....	.....	.....	280.7
712	278	.....	285	280	279	280	285	280	281	.....	.....	.....	281.0
755	272	280	279	286	.....	283	282	285	.....	.....	.....	.....	281.0
863	.....	279	279	280	279	.....	285	287	.....	.....	.....	.....	281.5
2263	.....	.....	.....	.....	.....	287	283	283	286	277	281	.....	282.8
2506	.....	272	.....	283	282	284	292	285	.....	.....	.....	.....	283.0
781	.....	.....	.....	287	281	.....	281	280	284	286	.....	.....	283.2
2070	.....	.....	.....	279	285	287	294	280	283	.....	.....	.....	284.7
2611	286	282	280	287	277	290	.....	.....	.....	.....	.....	.....	284.7
32B	276	290	288	284	285	287	284	.....	.....	.....	.....	.....	284.9
2642	282	286	284	284	288	286	.....	.....	.....	.....	.....	.....	285.0

Table 5 gives the length of gestation for 29 cows that have produced six or more calves. It can be readily seen that individual cows vary widely in the length of gestation. The smallest variation was six days and this degree of uniformity is shown by but one cow. Two cows showed a variation of seven days. The extreme variation was 20 days and there were two cows that varied that much. The cow number 2642, with a variation of only six days, had a standard deviation of 1.9149 and a coefficient of variation of 0.677 per cent, while cow number 2506, with a variation of 20 days, had a standard deviation of 5.8878 and a coefficient of variation of 2.080 per cent.

Many of the cows showed quite uniform gestation periods while others showed widely divergent periods. Some had quite uniform periods with perhaps only one period that was quite different from the others. An example of this is cow number 2506. It will be seen that her two-year old period was for only 272 days. Her next shortest period was for 282 days. She has periods of 283, 284, 285 and another somewhat widely diverging one of 292 days.

Another example is cow number 409. Five of her gestation periods range from 271 to 279 days, while the sixth was for 290 days.

Cow number 317 showed a steady increase in length of gestation period from her first calf as a two-year old until her last calf as an eight-year old. In contrast to this cow, number 2603 showed a decrease in length of gestation period from her second calf as a three-year old until her last calf as a seven-year old. Of the 29 cows considered, 15 had an extreme variation of from 12 to 20 days inclusive, while 14 had an extreme variation of from six to eleven days inclusive.

Table 6 gives the records of eleven high producing cows. The producing ability of these cows is indicated by the fact that one of them holds three world's records, another holds two world's records and a third holds one world's record.

In addition to the records of these cows, table 6 gives the length of time these cows were carried in dam, the number of calves each has produced, and the average length of the gestation periods of their calves.

In collecting data for this study, it was noticed that cow number 440 with two world's records to her credit was carried in dam only 270 days. Data were collected on the remainder of the cows given in the table to ascertain if there were other cows of outstanding merit that were carried in dam for periods that might be considerably below the average.

Cow number 2831 holds three world's records. She was carried in dam only 272 days. This cow is a very large and rugged cow, weighing about 2,000 pounds before freshening. She has dropped four fine calves, the first as a junior two-year old, the second as a senior three-year old, the third as a junior four-year old and the fourth as a six-year old. She is now just

TABLE 6

The Length of Gestation Periods of High Producing Cows

EAR TAG	MILK LBS.	FAT LBS.	AGE		CARRIED IN DAM	GESTATIONS	
			Years	Mo.		No.	Ave.
2831	29,082	1,198	4	10	272	4	273.0
3305	28,100	920	2	2	282	1	276.0
2787	28,967	939	2	6	262	4	282.0
2664	30,760	948	6	4	279	5	281.0
2803	23,879	992	4	3	289	4	283.0
2818	24,282	892	5	8	276	2	273.0
2841	27,831	951	5	1	289	3	284.7
2868	25,392	905	4	5	273	3	282.0
2819	25,118	910	5	6	284	4	274.5
2904	30,366	924	3	5	282	3	277.7
440	23,250	932	3	5	270	4	279.5

seven years old and is strong and healthy in every way and carrying her fifth calf.

Cow number 440 was carried in dam only 270 days. She calved first as a junior two-year old, making a record that ranked fifth for that age. She calved again as a junior three-year old and at that age made a world's record for ten months' production, calved again as a junior four-year old and made a world's record in the ten months' division for that age also. This cow has been a regular breeder as evidenced by the fact that she met the calving requirements for the ten months' division.

Cow number 3305 holds the world's record for milk production as a junior two-year old and was carried in dam 282 days.

Cow number 2787 has the second highest record in the world for her age. She was carried in dam only 262 days. She has calved regularly and has apparently not suffered any bad effects from the short time she was carried in dam.

These eleven high producing cows varied in the time that they were carried in dam from 262 to 289 days, with an average of exactly 278 days, which is 1.4 days lower than the average of all females included in this investigation. They have carried their calves an average of 278.8 days, which is an increase of 0.8 of a day in the direction of the general average.

In table 6 is given the length of time eleven cows were carried in dam and also the number of calves produced by these cows and the average gestation periods for these calves.

Cow number 2831 was carried in dam 272 days and the average gestation periods for her four calves were 273.0 days. In contrast to this, cow number 2787 was carried in dam only 262 days, while the gestation periods of her four calves averaged 282.0 days. The shortest period for any of this cow's calves was 275 days.

Cows 2831 and 2818 were both carried for short gestation periods and the periods of their calves also tend to be short. Cows 2803 and 2841 were both carried for periods longer than average and their calves were also carried for periods longer than the average. There seems to be no correlation whatever in the case of the other seven cows between the length of time they were carried in dam and the length of time they carried their calves.

While the number of cases available is too small to warrant any definite conclusions as to the effect of heredity on the length of gestation period, the data indicate that this may be a factor.

SUMMARY

1. The average number of days of 2,824 gestation periods studied that terminated with single births was 279.9 $\pm$ 0.063. Twins were born in 86 cases following gestation periods averaging 275.5 days.

2. The length of gestation periods varied from 262 to 296 days. Almost 75 per cent of all calves were dropped from the 275th to the 285th days inclusive. Only 1.7 per cent were carried for periods shorter than 270 days and 2.7 per cent were carried for 290 days or longer.

3. Male calves were carried an average of one day longer than female calves.

4. An increase in the length of gestation periods of approximately one and one-half days was observed as the age of the dams increased from two to six years. After the age of six years was reached there seemed to be a tendency for the gestation periods to become slightly shorter.

5. The gestation periods of calves sired by some bulls were definitely higher or lower than the average, indicating by their uniform divergence from the mean the possibility of paternal influence.

6. The least variation in length of gestation observed for 29 cows that had each produced six or more calves was six days. The greatest variation was 20 days. The length of gestation periods of some cows were quite uniform, while others varied widely.

7. Eleven exceptionally high producing cows were carried in dam an average of 278 days, or about one and one-half days less than the average for all females. The periods varied from 262 to 289 days.

8. In comparing the gestation periods of the above cows with the gestation periods of the calves they produced, it was found that four of the eleven cases showed a decided tendency for the calves of a cow to have gestation periods similar in length to her own.

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THE EFFECT OF PASTEURIZATION ON THE BACTERIAL FLORA OF LOW COUNT MILK[1]

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INTRODUCTION

The application of improved methods of milk production on dairy farms during the past few years has resulted in a marked reduction of the bacterial contamination of market milk. In certain localities this reduction has been so pronounced that it is a rather common occurrence for the bulk of the milk received at pasteurizing plants to contain only a few thousand bacteria per cc.

As a result of the pasteurization of this low count milk, certain problems have developed which were not often encountered when milk of a greater bacterial content was being passed through the pasteurizer. It has been observed that such milk frequently does not coagulate even after a considerable period of time. It has also been noted that the absence of coagulation is oftentimes accompanied by the development of pronounced off flavors and odors. The nature of these off flavors and odors is usually such as to indicate changes in the nitrogenous constituents of the milk.

Past investigations of the bacterial content of raw milk and the influence of subsequent pasteurization have been made upon milk with a relatively high bacterial content. The milk studied frequently contained many millions of bacteria per cc. In addition, most of the investigational work pertaining to the numbers and types of organisms surviving pasteurization was carried out a number of years ago and at a time when high count milk was the rule and not the exception.

Ayers and Johnson (1) made a detailed study of the groups of bacteria developing in both raw and commercially pasteurized milk held at the same incubation temperatures. Their particular objects were to determine to what extent the lactic acid bacteria developed, and to compare the development of various groups of bacteria in pasteurized and raw milk. They divided the bacteria found in milk into three groups; namely, the

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alkali forming and inert, the lactic acid forming, and the peptonizing. As the result of their investigation, they make the following statement:

> "Commercially pasteurized milk always sours because of the development of lactic acid bacteria which on account of their high thermal death point survive pasteurization and perhaps in some cases because of subsequent infection with acid forming bacteria during cooling and bottling."

They found the relative proportions of the various groups of organisms to be approximately the same in efficiently pasteurized milk as in clean, raw milk. The alkali forming and inert types constituted the largest group. The next largest group was composed of the lactic acid bacteria, while the peptonizers were in the minority. They found that when both the efficiently pasteurized and the clean, raw milk were held at the same temperature the group relations changed, but the changes taking place were similar in each type of milk. At the time of souring the lactic acid bacteria constituted the largest group. Next in order were the alkali forming and inert types while the peptonizers were in the minority as initially. The majority of the samples of milk used by these investigators contained an initial bacterial content in excess of a million organisms per cc.

In a further study of the bacteria surviving pasteurization temperatures, Ayers and Johnson (2) obtained results somewhat different from those they had previously reported. Using milk of high bacterial content, they found that the percentage of the acid forming group was increased by pasteurization and that the percentages of all of the other groups were decreased. When pasteurization was below a temperature of 170°F for 30 minutes the bacterial flora was composed for the most part of organisms of the acid producing group. In the same paper, they state that when the best quality, or low count milk, was pasteurized, it was the only grade of milk showing a decrease in the percentage of acid-coagulating organisms.

It is to be remembered, however, that these investigators divided the acid forming bacteria into two groups, the acid coagulating, which produced sufficient acid to curdle the milk within 14 days, and the acid non-coagulating, which produced acid more slowly and did not curdle the milk in 14 days. Although the percentage of the acid coagulating group was reduced by pasteurization, the percentage of the total acid group was increased by this treatment. The grade of milk to which they referred contained an average bacterial content of 24,000 per cc. This seems to indicate that even different results might be obtained when milk with a much lower bacterial content is pasteurized. It is reasonable to assume that in high quality milk as indicated by a low bacterial count the bacterial flora of the normal cow's udder may influence, to a considerable extent, the percentage of the various bacterial groups surviving pasteurization.

These investigators noted a difference in the changes occurring in the various grades of milk following pasteurization. First, when a milk of fair quality was pasteurized at 145°F. for 30 minutes under laboratory conditions and held at room temperature the acid producing group might develop at once and overgrow all the other groups, resulting in the formation of acid and the production of a normal curd. Second, when a poor quality milk was pasteurized the peptonizing bacteria might grow rapidly at first along with the acid forming bacteria, which later overgrew them. Third, when a good grade of milk was pasteurized the peptonizing organisms might overgrow the acid producing group, thereby resulting in the peptonizing of the milk without the development of acid.

In a more recent paper in which the status of pasteurization is discussed Ayers (3) makes use of the experimental data gathered in the researches previously mentioned and applies them to the conditions existing some 13 to 15 years later. While he recognizes that variations in methods and conditions of production may influence considerably the bacterial group relations of an individual sample, he states that under average conditions milk which has been pasteurized at 145°F. for 30 minutes will sour instead of decompose. The explanation for this is that in milk pasteurized at the above temperature the majority of the viable organisms are of the kind which produce acid and as the milk is held these forms develop more rapidly than do the peptonizing forms. The average sanitary conditions pertaining to the production, handling and distribution of market milk, as they exist at the present time, or as they existed a few years ago, are hardly comparable to the sanitary conditions that prevailed 18 to 20 years ago. In view of this greatly changed condition it is questionable if the experimental results obtained under the average condition of 18 to 20 years ago can be applied at the present time.

There is, therefore, a decided need for information on this problem as it exists in certain regions normally producing a low count milk. Accordingly, the experiments reported in this paper were designed to give information on the types of bacteria surviving the pasteurization of low count milk, the changes occurring in the developing flora subsequent to pasteurization and the relation of this flora to the changes taking place in the milk.

PROCEDURE

The samples of milk used in this investigation represented milk produced near the city of Pullman, Washington. No attempt was made to supervise the milking process, although care was taken to select samples from the morning milk. These were collected as soon as possible after milking, and taken to the laboratory at once. The milk sample was then divided into two equal portions and one portion pasteurized in a flask at a

temperature of 142.5° F. ± 0.5° for 30 minutes, after which it was closed immediately. Both raw and the pasteurized portions were divided again and a representative sample of each incubated at temperatures of 68°F. and 45°F., respectively. The sample under observation was examined for flavor daily and when an off flavor had developed so that the milk was unfit for consumption, it was considered spoiled.

In this study the bacteria contained within the milk were divided into three groups; the acid producing, the proteolytic, and a group including alkali forming and inert types. Differential and total bacterial counts were made on the raw and pasteurized portions at the time they were fresh and again at the time when spoilage was evident. These counts were determined by the use of Bacto-nutrient caseinate agar, a modification of the medium recommended by Ayers and Mudge (4). Prior to the sterilization of the medium a stock solution of indicator consisting of 0.4 gram of brom cresol purple, 7.4 cc. of N/10 NaOH and 92.6 cc. of distilled water was added to the agar at the rate of 8 cc.per liter. On plates poured with this medium the acid forming colonies appear yellow against a purple background, while the alkali forming colonies assume a purple color deeper than the surrounding medium. After these types have been enumerated the plate is flooded with dilute acetic acid. The proteolytic organisms are then distinguished by the clear halos surrounding the colonies. Those organisms that were not characterized by either acid forming, proteolytic or alkali forming properties were considered as inert types. Plate cultures were incubated at 37°C. for 48 hours.

Acidity and Cooledge score determinations were made on the raw and pasteurized portions of each sample at the time the samples were fresh and at the end of each 24-hour period throughout the incubation period.

PRESENTATION OF DATA

Bacterial Counts of Raw and Pasteurized Milk.

The initial bacterial counts of the 20 samples of milk used in this study ranged from 930 to 10,650 per cc. as determined by the use of caseinate agar plate cultures. Sixteen of these samples contained less than 5,000 per cc. The average bacterial count was 3,467 per cc. Pasteurization resulted in a reduction of the bacterial numbers ranging from 61.3 per cent to 99.95 per cent, with an average reduction of 89.1 per cent. The average number of organisms after pasteurization was 374 per cc.

Bacterial Groups Surviving Pasteurization and Developing in Raw and Pasteurized Milk Incubated at 68°F. and 45°F., respectively.

The bacterial groups in the raw and pasteurized samples were determined at the time the samples were fresh and again when the samples had

deteriorated to such an extent as to be unfit for consumption. The average initial percentages of these groups in raw and pasteurized milk, the average percentages after incubation and the average length of the incubation period for the various types of samples are shown in table 1.

TABLE 1

Average percentages of bacterial groups in fresh and incubated raw and pasteurized milk

TYPE OF MILK	BACTERIA PER CC.	PER CENT ACID FORMING	PER CENT PROTEOLYTIC	PER CENT ALKALI FORMING AND INERT	HOURS OF INCUBATION
Fresh raw milk	3,467	26.17	0.76	73.07	
Fresh pasteurized milk	377	14.64	0.62	84.74	
Raw milk incubated at 68°F.	977,000,000	68.69	0.038	31.25	54
Pasteurized milk incubated at at 68°F.	358,000,000	22.51	23.74	53.76	103
Raw milk incubated at 45°F.*	164,700,000	62.15	11.29	25.56	137
Pasteurized milk incubated at 45°F.**	69,240,000	11.38	13.85	74.77	164

* Average of 18 samples.

** Average of 16 samples.

As the result of pasteurization the acid forming group of organisms decreased from 26.17 per cent to 14.6 per cent of the total flora. This decrease is within the limits of random sampling and, therefore, it is not of statistical significance. The ratio of the proteolytic group to the other groups of organisms remained practically unchanged. The alkali forming and inert group increased from 73.07 per cent in the raw to 84.74 per cent in the pasteurized milk. Although this group showed a considerable increase this difference cannot be considered statistically significant for the reason stated above.

A rather wide variation in the percentages of the acid forming bacteria existed among individual samples of both fresh raw and pasteurized milk. A similar conditions existed in the percentages of the alkali forming and inert group, while with the percentages of the proteolytic group this variation was not pronounced.

In each type of milk the proteolytic group constituted only a small proportion of the flora. Fifteen samples of the raw and 17 samples of the pasteurized milk contained less than 1.0 per cent of these types of bacteria. In no sample of either kind of milk did they exceed 6.0 per cent of the total flora. The percentage variations of the acid producing group and the alkali forming and inert group contained within the samples of each type of milk are shown in figures 1 and 2 respectively. The number of samples

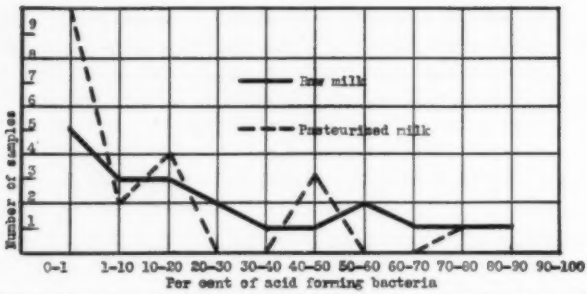
Raw milk
Pasteurized milk
Number of samples
0-1 1-10 10-20 20-30 30-40 40-50 50-60 60-70 70-80 80-90 90-100
Per cent of acid forming bacteria

FIG. 1. COMPARISON OF THE INITIAL PERCENTAGES OF ACID FORMING BACTERIA IN SAMPLES OF LOW COUNT RAW AND PASTEURIZED MILK

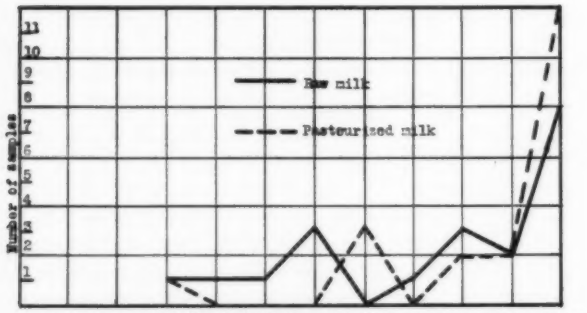
Raw milk
Pasteurized milk
Number of samples
0-1 1-10 10-20 20-30 30-40 40-50 50-60 60-70 70-80 80-90 90-100
Per cent of alkali forming and inert types of bacteria

FIG. 2. COMPARISON OF THE INITIAL PERCENTAGES OF ALKALI FORMING AND INERT TYPES OF BACTERIA IN SAMPLES OF LOW COUNT RAW AND PASTEURIZED MILK

was plotted as ordinates and the percentage of the groups of organisms as abscissae, the ranges in percentage from 0–1, 1–10, 10–20, etc., being taken as points. It will be seen from the frequency curves thus obtained that pasteurization increased the number of samples in which the acid producing bacteria constituted 20 per cent or less of the total flora. In a like manner pasteurization increased the number of samples in which the alkali forming and inert group composed 70 per cent or more of the total flora.

Ayers and Johnson (2) grouped the milk with which they worked into three grades. The average bacterial content per cc. for each of these grades was as follows: A—32,000,000 (20 samples), B—3,500,000 (24 samples), and C—24,700 (12 samples). These investigators separated the acid producing bacteria into two groups; the acid coagulating and the acid non-coagulating. They also reported an alkali forming group and an inert group of bacteria. For the sake of comparison if the acid forming bacteria are combined into one group, and the alkali forming and inert groups com-

bined in a like manner we find the group percentages as reported by them immediately before and after pasteurization at 145° F. for 30 minutes to be as follows:

GRADE		PER CENT ACID FORMING	PER CENT PROTEOLYTIC	PER CENT ALKALI FORMING AND INERT
A	Raw	46.88	17.31	35.78
	Past.	79.78	1.39	18.83
B	Raw	22.72	14.10	63.17
	Past.	66.76	29.23	3.59
C	Raw	40.70	12.81	46.46
	Past.	73.10	4.47	22.43

In each of the three grades of milk pasteurization resulted in an increase in the percentages of the acid forming group and a decrease in the percentages of the alkali forming and inert group. Opposite results were obtained in our experiment. Pasteurization resulted in a decrease in the acid forming group and an increase in the alkali producing and inert group, although these differences were not great enough to be of statistical significance.

A comparison of the final differential counts of the raw and pasteurized milk samples incubated at 68°F. show some significant differences in the development of the different groups of bacteria. The predominating group in the raw samples was composed of the acid producing types, while in the pasteurized samples the majority of the bacteria were of the alkali forming and inert types. A comparison of the percentages of the groups composing the total flora in the raw and pasteurized milk shows the acid producing group to average 68.69 per cent and 22.51 per cent respectively. The difference in percentages is so great that it assumes statistical significance. The pasteurized milk spoiled with a decided off flavor and in a few cases showed evidence of proteolysis. The acid producing types in the pasteurized milk remained the least abundant. The proportion of the proteolytic types was considerably greater in the pasteurized than in the raw samples, being increased from 0.038 per cent in the raw milk to 23.74 per cent in the pasteurized milk. The alkali forming and inert group was also considerably greater in the pasteurized than in the raw milk. Since in the pasteurized samples the acid producing group was in the minority, this group probably had an unimportant part in the spoiling of the milk even though the samples were incubated for a longer period than the raw milk samples.

The most striking variations in the percentage of the groups of bacteria developing in the raw and pasteurized milk samples incubated at 68°F.

occurred in the acid forming and the alkali producing and inert groups. The proteolytic group percentages showed no variation in the samples of the raw milk, but did show a considerable variation in the case of a number of samples of the pasteurized milk. None of the raw and only eight of the pasteurized milk samples contained proteolytic organisms in excess of 1.0 per cent of the total flora. Four of the samples of the pasteurized milk contained organisms of this group in sufficient numbers so that they constituted 80 per cent or more of the bacteria present. The proteolytic group in each of these four samples, immediately following pasteurization and prior to incubation, constituted less than 1.0 per cent of the flora. These organisms were able to overgrow an initial predominating flora composed almost entirely of alkali forming and inert types of bacteria. Frequency curves showing the variations in the percentages of the acid forming and the alkali producing and inert groups of bacteria in the samples of each type of milk are shown in figures 3 and 4 respectively.

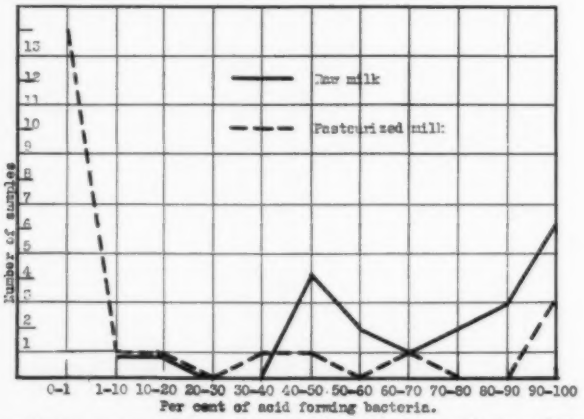
Raw milk
Pasteurized milk
Number of samples
0-1 1-10 10-20 20-30 30-40 40-50 50-60 60-70 70-80 80-90 90-100
Per cent of acid forming bacteria.

FIG. 3. COMPARISON OF THE PERCENTAGES OF ACID FORMING BACTERIA DEVELOPING IN SAMPLES OF LOW COUNT RAW AND PASTEURIZED MILK INCUBATED AT 68°F.

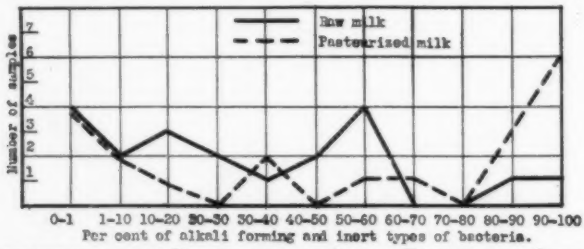
Raw milk
Pasteurized milk
Number of samples
0-1 1-10 10-20 20-30 30-40 40-50 50-60 60-70 70-80 80-90 90-100
Per cent of alkali forming and inert types of bacteria.

FIG. 4. COMPARISON OF THE PERCENTAGES OF ALKALI FORMING AND INERT BACTERIA DEVELOPING IN SAMPLES OF LOW COUNT RAW AND PASTEURIZED MILK INCUBATED AT 68°F.

From these curves, it will be seen that the acid forming group of organisms constituted more than 50 per cent of the bacterial flora in 14 of the raw milk samples as compared to four samples of the pasteurized milk containing like percentages of this group of organisms.

In 12 of the pasteurized milk samples these bacteria constituted less than 1.0 per cent of the organisms present. The alkali and inert group of bacteria composed 60 per cent or more of the flora in 10 of the pasteurized samples, whereas a like number were present in only two samples of the raw milk.

In the samples incubated at 45°F. the acid producing group predominated in the raw and the alkali forming and inert group predominated in the pasteurized milk. The acid producers in the raw and pasteurized milk averaged 62.15 per cent and 11.38 per cent respectively. Statistically this is a significant increase of the acid forming group in the raw milk over the

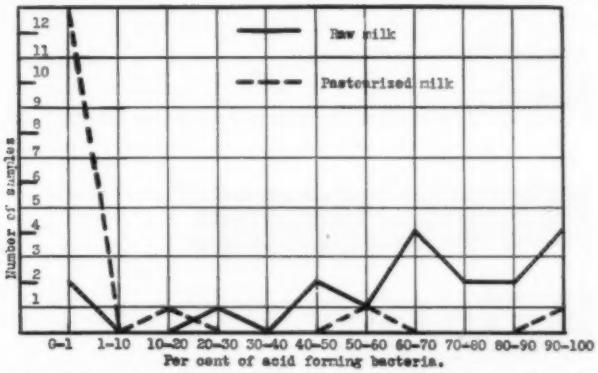

FIG. 5. COMPARISON OF THE PERCENTAGES OF ACID FORMING BACTERIA DEVELOPING IN SAMPLES OF LOW COUNT RAW AND PASTEURIZED MILK INCUBATED AT 45°F.

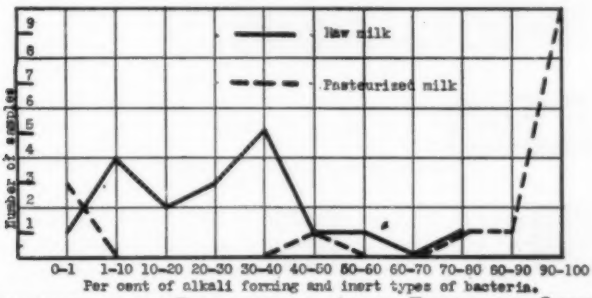

FIG. 6. COMPARISON OF THE PERCENTAGES OF ALKALI FORMING AND INERT BACTERIA DEVELOPING IN SAMPLES OF LOW COUNT RAW AND PASTEURIZED MILK INCUBATED AT 45°F.

acid forming group in the pasteurized milk. The percentage of proteolytic bacteria averaged 11.29 in the raw milk and 13.85 in the pasteurized milk. In the pasteurized milk the alkali forming and inert group predominated with an average of 74.77 per cent, while in the raw milk only 25.56 per cent of the flora was of this group. Statistically this is a significant increase. Although the low holding temperature had a decided retarding effect on the development of all bacteria, the raw milk eventually spoiled, due to the action of acid producing bacteria. The pasteurized milk, even though held 28 hours longer than the raw milk, did not sour but spoiled apparently due to the action of the proteolytic and the alkali forming and inert groups of bacteria.

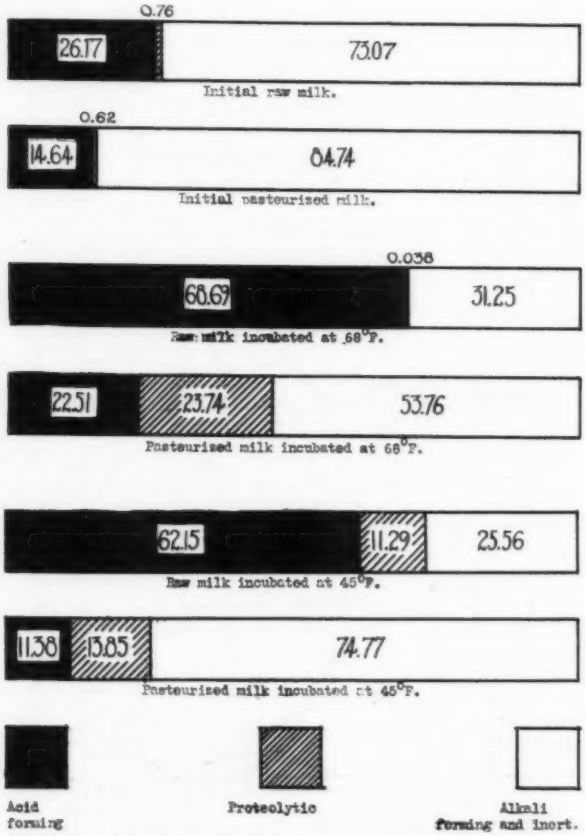

FIG. 7. COMPARATIVE PERCENTAGES OF BACTERIAL GROUPS DEVELOPING IN INCUBATED RAW AND PASTEURIZED MILK

The variations in the percentages of the acid forming group and the alkali producing and inert group of organisms in both raw and pasteurized samples incubated at 45°F. were very similar to those found in the samples incubated at 68°F. With both raw and pasteurized milk the proteolytic group of organisms constituted less than 10 per cent of the total flora in the majority of the samples. This group composed 70 per cent or more of the total flora in only two samples of each type of milk.

Frequency curves showing the variations in the percentages of the acid forming and the alkali forming and inert groups of bacteria in the samples of each type of milk are shown in figures 5 and 6 respectively. The acid producing group constituted 50 per cent or more of the bacterial flora in 13 of the 18 samples of raw milk while in 13 of the 16 samples of pasteurized milk less than 1.0 per cent of the flora was composed of this group of organisms. Organisms of the alkali forming and inert group of bacteria constituted less than 40 per cent of the flora in 15 of the 18 samples of raw milk. This same group of bacteria made up 70 per cent or more of the flora in 12 samples of the pasteurized milk.

The average percentages of the various groups of bacteria developing in raw and pasteurized milk at the two above incubation temperatures are shown graphically in figure 7.

The Cooledge Score of Raw and Pasteurized Milk Incubated at 68°F. and 45°F.

In the determination of the Cooledge score Bacto-Cooledge broth was used following the technique of Devereaux (5). The average scores for the 20 samples of each of the above series are shown in table 2.

TABLE 2

Average Cooledge scores of low count raw and pasteurized milk incubated at 68° F. and at 45° F.

TYPE OF MILK	NO. OF SAMPLES	0 HRS.	24 HRS.	48 HRS.	72 HRS.	96 HRS.
Raw milk at 68°F.	20	98	75	58		
Past. milk at 68°F.	20	99	93	84		
Raw milk at 45°F.	20	98	91	86	77	69
Past. milk at 45°F.	20	99	98	98	95	90

At both temperatures the decrease in score of the pasteurized samples was slower and did not reach as low a point as it did in the raw samples. Since this test is based upon the development of acid in the test medium, the results obtained in this experiment furnish additional evidence that the acid producing types were less active in the pasteurized than in the raw milk held at the same incubation temperature.

Acid Development in Raw and Pasteurized Milk Incubated at 68°F. and 45°F.

The acidity of the milk was calculated as the percentage of lactic acid. The results obtained are given in table 3.

TABLE 3

Average acidity of raw and pasteurized milk incubated at 68°F. and at 45°F.

TYPE OF MILK	NO. OF SAMPLES	0 HRS. PER CENT ACID	24 HRS. PER CENT ACID	48 HRS. PER CENT ACID	72 HRS. PER CENT ACID	96 HRS. PER CENT ACID
Raw milk at 68°F.	20	0.18	0.19	0.51		
Past. milk at 68°F.	20	0.18	0.19	0.20	0.21	0.23
Raw milk at 45°F.	20	0.18	0.18	0.19	0.22	0.27
Past. milk at 45°F.	20	0.18	0.18	0.18	0.18	0.19

From the results of these determinations, it is very evident that the acid producing flora developed more rapidly in the raw than in the pasteurized milk. This is especially striking in the milk incubated at 68°F. After 48 hours of incubation, 13 of the raw milk samples had reached an acidity in excess of 0.5 per cent, whereas the highest acidity recorded for any sample of the pasteurized milk at the end of 96 hours' incubation was 0.43 per cent. The acid producing bacteria which were found to predominate in four samples of the pasteurized milk apparently were of the non-coagulating type. Even after a period of 96 hours, the acidity of the milk incubated at 45°F. had increased but little. This is especially true of the pasteurized samples. At the end of this time, seven of the raw milk samples had reached an acidity greater than 0.3 per cent, ranging from 0.31 per cent to 0.57 per cent, while none of the pasteurized milk samples showed an acidity of more than 0.23 per cent. These results indicate that the acid forming bacteria which develop in raw milk at 45°F. consist for the most part of the non-coagulating type. Since an increase in acidity is due to an increase in the numbers of acid forming bacteria, there was a greater preponderance of these forms of organisms in the raw than in the pasteurized milk at the time of spoilage. These results substantiate the differential count and the Cooledge score determinations.

SUMMARY AND CONCLUSIONS

Plate counts were made on 20 samples of milk before and after pasteurization. The average count before pasteurization was 3,467 per cc. and after pasteurization 377 per cc.

The bacterial flora of the raw and pasteurized milk was divided into three principal groups: the acid producing, the proteolytic and the alkali forming and inert. In the raw milk the acid producers composed 26.17

per cent, the proteolytic 0.76 per cent, and the alkali forming and inert 73.07 per cent of the bacterial flora present. In the freshly pasteurized milk the acid producers composed 14.64 per cent, the proteolytic group 0.62 per cent and the alkali forming and inert group 84.74 per cent of the organism present.

Raw milk was incubated at 68°F. until it spoiled. The acid group increased from 26.17 per cent to 68.69 per cent, and the proteolytic group decreased from 0.76 per cent to 0.038 per cent. The alkali forming and inert group decreased from 73.09 per cent to 31.25 per cent. When the raw milk was incubated at 45°F. until it spoiled the acid forming group increased from 26.17 per cent to 62.15 per cent. The proteolytic group increased from 0.76 per cent to 11.29 per cent and the alkali forming and inert group decreased from 73.07 per cent to 25.56 per cent.

Pasteurized milk was incubated at 68°F. until it spoiled. The acid producers increased from 14.64 per cent to 22.51 per cent. The proteolytic group increased from 0.62 per cent to 23.74 per cent and the alkali forming and inert group decreased from 84.74 per cent to 53.76 per cent. When incubated at 45°F. the acid group decreased from 14.64 per cent to 11.38 per cent. The proteolytic group increased from 0.62 per cent to 13.85 per cent and the alkali forming and inert group decreased from 84.74 per cent to 74.77.

Cooledge score and titratable acid determinations were made on both raw and pasteurized samples at the beginning of the experiment and every 24 hours until the milk spoiled. Both of these tests furnished additional evidence relative to the groups of organisms responsible for the changes occurring in incubated raw and pasteurized milk.

These results indicate that when milk of low initial bacterial content is pasteurized the acid producing bacteria are not of major importance in the spoilage of the milk. This may account in part for the trouble occurring in certain localities where low count milk is being pasteurized. Such milk often spoils with a decided off flavor and odor, but without the usual evidence of souring. From the results of this investigation it seems likely that this trouble may be attributed to the action of the proteolytic and the alkali forming and inert types of bacteria. This may especially be true when contamination subsequent to the pasteurizing process is eliminated.

The evidence reported in this paper bearing on the groups of bacteria surviving pasteurization and causing the subsequent changes in milk does not fully agree with the results obtained by other investigators. The conclusions reached by these investigators were based on experiments with milk of relatively high bacterial content. Their milk samples frequently contained many millions of bacteria per cc. while in our study a low count milk was used.

In this investigation, it is recognized that a sufficient number of samples have not been studied to warrant the formulation of definite conclusions. It is felt, however, that the observations recorded in this paper are indicative of the bacteriological changes which result when a very low count milk is pasteurized under commercial conditions.

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THE FOOD VALUE OF FROZEN EVAPORATED MILK

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Very little work has been done to determine whether or not the freezing of milk changes its food value. It is important to determine this point as many people, including nutritionists, have believed frozen milk to be deleterious to health. The thought that something has gone wrong has probably resulted from the fact that freezing does cause a change in the appearance of the milk. There is frequent opportunity for evaporated milk to become frozen, particularly that which is used in arctic regions.

Anderson and Pierce (1) in a recent article state that the precipitation of milk protein from raw and sterile skim milk takes place after 2 months' storage at + 10° F. and after 3 months' storage at – 14° F. They also state that some slight chemical changes must take place in the milk stored as above inasmuch as they were able to detect an increase of amino-nitrogen. Smith (2), in 1922, studied the vitamins in ice cream and found that for vitamin A "no noteworthy alteration in its potency was caused by pasteurization and freezing." Normal growth in rats was induced by the addition of one gram of ice cream (10% fat) per day to the diet, and xerophthalmia was cured by amounts as small as 0.25 grams containing but 25 milligrams of butter fat. Freezing has no effect on vitamin B, and ice cream made from pasteurized products was found to contain very little vitamin C.

The procedure followed in the experiment herein described consisted in feeding separate sets of albino rats on evaporated milk which had been stored in a normal manner and evaporated milk which had been frozen in cold storage and observing the rate of growth of each set of rats.

All evaporated milk used was of the date of May 8, 1930. Part was stored under normal storage conditions and part was stored 5 months and 20 days at – 5° F., followed by 30 days' storage at normal temperatures.

The albino rats used were 27 days old at the start of the experiment and weighed about 40 grams each. Twenty-two rats were fed the frozen-thawed evaporated milk and twenty were fed the normal evaporated milk. All rats were on a milk diet entirely, being given all the milk which they would consume. All of the milk was diluted with distilled water to the consistency of ordinary market milk before feeding (1 : 1). Osborne and Mendel (3) in their experiments reached the conclusion that rats required at least 16 grams of ordinary milk daily for normal growth. It was found in this experiment that the rats would consume usually more than 16 grams of evaporated milk daily, equivalent to more than 32 grams of ordinary milk.

At the start of the experiment all rats developed "scours" as a result of being placed on an exclusively liquid diet. During this period no difference

could be seen between rats on the different milk, and in two weeks both sets of rats had adjusted their systems to the liquid diet.

Tables 1 and 2 give the gain in weight of the rats on the different milks over a period of 12 weeks, and the averages. The figures in the column on

TABLE 1

Weight of rats in grams fed evaporated milk not frozen

RAT NO.	AT START	1ST WEEK	3RD WEEK	6TH WEEK	9TH WEEK	12TH WEEK	AV. MILK (DILUTED) CONSUMED PER DAY
							grams
1	36	52	61	82	105	120	36.0
2	29	35	44	Died	.....	.....	.....
3	31	41	65	74	66	71	30.4
4	37	44	61	75	93	106	36.0
5	40	50	54	44	Died	.....	.....
6	31	43	55	59	59	50	28.7
7	44	56	67	82	97	108	36.0
8	40	49	70	71	92	108	36.0
9	38	50	59	68	82	95	31.5
10	37	50	62	78	96	114	36.0
11	42	45	63	70	81	109	31.0
12	49	46	55	61	75	92	30.0
13	50	49	55	63	80	113	31.0
14	41	46	62	68	84	109	31.0
15	42	40	56	73	80	92	30.0
16	38	40	52	61	80	104	31.0
17	40	44	54	64	81	105	30.0
18	44	40	47	60	74	101	31.0
19	40	42	55	65	76	94	31.0
20	41	36	49	59	67	84	27.0
Average gain	.....	5.4	17.8	27.7	42.0	57.1	

the extreme right show the average amount of milk consumed daily by each rat.

SUMMARY

The growth of young rats on normal evaporated milk and on frozen-thawed evaporated milk was determined.

The data show that during the 12 weeks' period of the experiment the rats fed on normal evaporated milk made an average gain in weight of 57.1 grams on an average daily food consumption of 32.1 grams (in terms of ordinary milk). In comparison, the rats fed on frozen-thawed evaporated milk made an average gain of 58.2 grams on an average daily food consumption of 33 grams.

It will be noted that the rats fed on frozen-thawed evaporated milk consistently made the larger gain in weight for any given period. However the

TABLE 2

Weight of rats in grams fed frozen-thawed evaporated milk

RAT NO.	AT START	1ST WEEK	3RD WEEK	6TH WEEK	9TH WEEK	12TH WEEK	AV. MILK (DILUTED) CONSUMED PER DAY
							grams
21	40	48	61	75	91	105	36.0
22	43	51	57	63	96	110	32.2
23	38	48	67	75	90	105	36.0
24	43	51	70	75	90	103	36.0
25	42	54	72	76	90	102	36.0
26	41	56	73	86	96	109	36.0
27	43	53	68	77	89	101	36.0
28	42	56	69	79	96	106	36.0
29	41	53	71	87	103	112	36.0
30	43	57	69	85	103	114	36.0
30A	44	54	68	70	80	83	33.8
31	48	44	54	66	82	104	31.0
32	43	39	51	62	83	104	31.0
33	43	39	49	61	76	91	31.0
34	38	40	50	60	76	92	31.0
35	40	38	47	54	67	90	30.0
36	42	43	47	55	65	64	30.0
37	47	42	52	63	75	90	31.0
38	41	41	55	71	89	105	31.0
39	45	43	52	60	76	94	31.0
40	39	38	50	62	77	100	31.0
41	41	40	48	64	75	91	29.0
Average gain	.....	6.1	18.4	28.4	44.1	58.2	

difference between the two sets of rats is small, amounting to only 1.1 grams at the end of twelve weeks and is to be accounted for by the fact that the rats fed on frozen-thawed evaporated milk consumed on an average of 0.9 grams of milk more per day.

Based upon the growth data and upon the fact that all rats were in good physical condition at the end of the experiment, we can conclude that none of the food value of evaporated milk is destroyed by freezing, and neither is there produced any substance deleterious to health.

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THE CHEMISTRY OF THE BLOOD OF DAIRY COWS BEFORE AND AFTER PARTURITION AND ITS RELATION TO MILK FEVER

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INTRODUCTION

The disease milk fever has been known to dairymen for over 100 years. Since Schmidt's well known discovery in 1897 the treatment of this disease has been quite simple, but until recently, veterinarians have had only numerous and somewhat vague theories as to the cause of the disease. However, recent biochemical work has given us some definite information on the nature of milk fever.

The various phases of this disease have been covered quite thoroughly in recent reviews by Greig (11), Harding (12), Little and Wright (19), and Hayden and Scholl (14). The more recent theories on the cause of milk fever center around ideas of disturbances in metabolism or internal secretions, which may occur at the onset of lactation.

The hypoglycemia theory has been the subject of considerable investigation. It was started by the observation of the similarity of the symptoms of milk fever to those of insulin hypoglycemia. However, Hayden (13) and Fish (4) have investigated this question quite thoroughly and have extensive data showing that in milk fever there is a hyperglycemia rather than a hypoglycemia. They found that before inflation for milk fever the blood sugar was above normal and that it rose after inflation, later coming back towards normal. Lactose, as well as glucose, was found in the blood and in the urine after inflation.

Recent work on milk fever has focused attention on the blood Ca and blood P, particularly the Ca. Little and Wright (18) reported blood Ca determinations on 12 cows affected with milk fever. They found decreases below normal of 20 to 30 per cent in mild cases, and up to 60 per cent in severe ones. They also stated that 30 to 40 cc. of 10 per cent $CaCl_2$ solution injected intravenously or intramuscularly had a beneficial effect. Dryerre and Greig (2) advanced as a working hypothesis the idea of a parathyroid deficiency being a factor in this disease. Greig (11) gives data on 82 milk fever cases in which the average serum Ca was 5.13 mg. per 100 cc. while the minimum and maximum values were 3.00 and 7.76 respectively. It was found that udder inflation in milk fever cases caused a rise in serum Ca,

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which continued on above the normal and then returned to normal, the maximum occurring at 3 to 5 days after inflation. Greig suggested the injection of calcium gluconate solution as a treatment, and he (10) reported 32 cases, which were given this treatment, 23 of which recovered rapidly and completely as the result of one injection. The other 9 cases were given a second injection or the udder was inflated. Sjollema (24) reported low values for both Ca and P of the serum in 40 milk fever cases. He recommended injection of 300 to 400 cc. of 10 per cent $CaCl_2$ solution, and got reports of very good results from veterinarians who used this treatment. Fish (5) reported the following values for 25 milk fever cases: Ca, average 3.31 mg. per 100 cc., minimum and maximum, 1.75 and 6.00 respectively; P, average 2.39 mg. per 100 cc., minimum and maximum, less than 1 and 4.25 respectively. He found that after inflation in milk fever cases, the P returns to normal and goes on above normal in 6 to 8 hours, while on the average the Ca was still below normal after 24 to 36 hours.

Harding (12) has advanced the idea of anhydremia being present in milk fever. He believes that shock resulting from anhydremia could be responsible for all of the symptoms of milk fever. However, he admits that this theory does not explain satisfactorily the low blood Ca and P values which occur.

Although considerable work has been done on the chemistry of the blood in cases of milk fever, little has been reported on the changes in the blood, if any, that take place in normal parturitions. Dryerre and Greig (3) report data on two cows calving normally, which indicate a slight fall in serum Ca at the so-called milk fever period. Palmer, Cunningham and Eckles (21) found that normal parturition caused a decrease in inorganic P. They have also presented considerable data on the normal variations in the P of the blood of dairy cows. They found quite marked day to day variations, even when the blood was drawn under apparently identical conditions. Palmer and Eckles (22) report data on the normal variations in serum Ca.

It was considered that a study of the blood variations in case of normal calvings might reveal more definite knowledge as to just what factors are responsible for milk fever, and why some cows have it and other cows calving under very similar conditions do not. We do not know whether the disturbances that bring on milk fever are present in all parturitions, and only show their effect when they become acute, or whether milk fever is due to some peculiar or unusual disturbance. The investigation which is being reported was carried out with these ideas in mind.

INVESTIGATIONAL

Analyses were made of blood samples taken before and after calving from cows in the dairy herd of the Wisconsin Experiment Station. At first

two samples only were taken, in most cases, one before calving and one after. Usually the samples were taken within a day of the time of calving. The samples were drawn from the jugular vein and were analyzed for total serum Ca, inorganic serum P, total sugar, and in a few cases, for non-fermentable reducing substance. Ca was determined by the Clark and Collip (1) method and P by the Fiske and Subbarow (6) method. With cow's blood the serum does not separate from the clot to any extent when it is cold, and for this reason the samples were set in the incubator for about an hour after they had clotted. It was found that the results on samples so treated checked very well with those on samples that were centrifuged immediately after drawing before the blood had clotted firmly. Total sugar and non-fermentable reducing substances were determined by the Folin and Svedberg (7) method. For sugar determinations blood samples of 10 to 20 cc. were collected in test-tubes containing 7 drops of 6.25 per cent potassium oxalate solution dried on the inside.

A summary of the data obtained in this preliminary work is given in tables 1 and 2. It will be seen that the values obtained for Ca and P vary considerably around calving time, but the variations are not consistent. In some cases these values are higher after calving, and in about an equal number of cases they are lower after calving. These data suggest that more significant results might be secured if more than two blood samples were taken for each individual case. Therefore, in continuing this work it was decided to take samples several days before calving and several days after, as well as samples very near the time of calving. The samples were analyzed for total Ca and inorganic P as before. Sugar determinations were discontinued as the blood sugar level is apparently not an important factor in the etiology of milk fever. In addition to Ca and P, the blood proteins; albumin, globulin, and hemoglobin, were determined. This was done to determine if there is any evidence of anhydremia in normal calvings, or in milk fever, as suggested by Harding (12). It was also considered interesting to see if the large amount of globulin secreted in the colostrum milk would affect the level of globulin in the blood.

The serum albumin and globulin were determined by the Greenberg (9) method. The results were calculated on the basis of the tyrosine equivalents of these proteins given by Greenberg for human blood. The hemoglobin was determined by the Newcomer (20) method using a Bausch and Lomb filter as a standard. Oxalated blood was used for all of the protein determinations. The data on individual cases for which blood proteins and total Ca and inorganic P were determined are given in table 3.

Later the protein determinations were discontinued and plasma phosphatase activity was determined. This enzyme was discovered in bone by Robison in 1923 and there is evidence that it plays an important rôle in bone formation. It is also found in other tissues. Kay (17) found that

TABLE 1

Average blood Ca, P and sugar values for cows before and after calving

Grouped according to the times the blood samples were taken

BLOOD CONSTITUENT	TIMES		NO.	BEFORE CALVING	AFTER CALVING	RISE AFTER CALVING			FALL AFTER CALVING		
	Before calving	After calving				No.	Ave.	Max.	No.	Ave.	Max.
Tot. sugar mg. per 100 cc. of blood	Over 10 hrs.	Over 10 hrs.	3	53.5	48.2	1	1.8		2	8.8	16.1
	Over 10 hrs.	10 hrs. or less	3	81.2	75.4	1	5.6		2	11.1	13.0
	10 hrs. or less	Over 10 hrs.	3	54.7	49.6	0			3	4.96	7.9
	10 hrs. or less	10 hrs. or less	4	68.2	72.2	2	16.9	22.9	2	8.9	13.8
Totals.....			13	64.7	62.2	4	10.3	22.9	9	8.03	16.1
	Before calving	After calving									
Ca. mg. per 100 cc. serum	Over 10 hrs.	Over 10 hrs.	3	10.5	10.4	1	0.2		1	0.6	
	Over 10 hrs.	10 hrs. or less	3	9.4	10.4	2	2.1	3.8*	1	1.5	
	10 hrs. or less	Over 10 hrs.	5	9.4	9.9	5	0.5	0.8	0		
	10 hrs. or less	10 hrs. or less	7	9.6	9.5	3	0.6	1.3	4	0.8	1.5
Totals.....			18	9.68	9.89	11	0.78	3.8*	6	0.81	1.5
	Before calving	After calving									
P. mg. per 100 cc. serum	Over 10 hrs.	Over 10 hrs.	3	7.41	5.96	1	0.23		2	2.32	2.66
	Over 10 hrs.	10 hrs. or less	3	5.00	5.59	2	1.10	1.99	1	0.43	
	10 hrs. or less	Over 10 hrs.	5	5.60	6.31	2	2.54	2.81	3	0.51	0.71
	10 hrs. or less	10 hrs. or less	7	5.29	5.88	5	1.30	2.54	2	0.62	1.71
Totals.....			18	5.67	5.97	10	1.40	2.81	8	0.98	2.66

* This figure may be questioned as the blood sample was frozen and hemolyzed considerably.

TABLE 2

Average blood Ca, P, and sugar values

Where samples were taken at two different times after calving

CONSTITUENT	NO. OF CASES	LESS THAN 10 HRS. AFTER	OVER 10 HRS. AFTER	RISE			FALL		
				No.	Ave.	Range	No.	Ave.	Range
Tot. Sugar mg. per 100 cc. of blood	4	91.2	59.9	0			4	31.3	3.2–70.9
Ca mg. per 100 cc. of serum	5	9.4	10.1	4	1.2	0.6 –2.1	1	1.2	
P mg. per 100 cc. of serum	5	5.42	6.01	4	1.48	0.83–2.63			

the plasma phosphatase is high in generalized bone diseases such as rickets and osteomalacia. He considers that the phosphatase in the blood plasma is present largely as the result of a leakage or slow diffusion from other tissues. Various workers have shown that high producing dairy cows frequently go into negative Ca balances for considerable lengths of time. In such cases the Ca is evidently being withdrawn from the bones. Since a high plasma phosphatase is present in rickets and in osteomalacia, where bone decalification is going on, it was thought that some significant variations might be found in the amount of this enzyme in the blood of dairy cows before and after calving, and in cases of milk fever. The phosphatase was determined by the method of Kay (16). The data on individual cases for which plasma phosphatase and inorganic Ca and P were determined are shown in table 4.

Phosphatase activity was also determined in the milk as well as the blood plasma of a few cows. Some low phosphatase values were found in the plasma of some of the heavily producing cows and this suggested that there might be some elimination of the enzyme from the blood through the milk. The phosphatase in the milk was determined in the same way as in the plasma (except for a slight modification) so that the data on the activities of the two fluids may be considered comparable. The data on this work are given in table 5. These data show that the phosphatase activity of the milk is usually greater than that of the plasma, particularly in cows near the end of lactation. The amount in the milk is roughly, inversely proportional to the amount of milk being secreted. This suggests that the enzyme may occur in the tissues of the udder, and it is possible that it plays a rôle in the phosphorus metabolism involved in milk secretion. It is at least

TABLE 3

Analyses of normal cows' blood before and after calving for blood proteins and total Ca and inorganic P

Hemoglobin = % of whole blood; albumin and globulin = % of serum; Ca and P = mg. per 100 cc. serum

COW NO. AND LACTATION		BEFORE CALVING		AFTER CALVING	
No. 1	Time	11 days	2 hrs.	14 hrs.	7 days
1st Lact.	Hemoglobin				
	Albumin	3.59	3.94	3.39	3.52
	Globulin	3.54	2.66	2.98	3.02
	Ca	11.5	11.7	11.0	10.7
	P	5.40	3.86	5.78	6.34
No. 2	Time	12 days		2½ hrs.	9 days
3rd Lact.	Hemoglobin			12.35	11.05
	Albumin	3.70		5.28	4.86
	Globulin	2.50		3.83	2.49
	Ca	10.8		10.6	11.8
	P	5.00		3.44	4.12
No. 4	Time	5 days	8½ hrs.	12½ hrs.	5 days
1st Lact.	Hemoglobin		8.80	8.08	8.30
	Albumin	3.62	4.58	4.38	3.42
	Globulin	1.76	2.23	2.22	2.12
	Ca	12.1		9.6	10.8
	P	5.28		8.42	5.74
No. 5	Time	7 days		3½ hrs.	7 days
1st Lact.	Hemoglobin	7.63		11.49	9.92
	Albumin	3.88		4.42	4.86
	Globulin	2.12		3.48	3.64
	Ca	9.8		9.8	9.5
	P	6.68		4.98	5.02
No. 6	Time	14 days		1 hr.	7 days
1st Lact.	Hemoglobin	9.92		12.35	10.75
	Albumin	4.25		4.28	3.80
	Globulin	3.12		2.81	3.06
	Ca	10.6		10.1	10.9
	P	5.46		3.70	6.72
No. 7	Time	10 days		2 hrs.	9 days
4th Lact.	Hemoglobin	11.83		11.16	10.00
	Albumin	3.64		3.74	3.86
	Globulin	3.22		3.31	3.96
	Ca	11.1		10.4	11.2
	P	6.52		2.84	5.12
No. 8	Time	6 days		2½ hrs.	6 days
1st Lact.	Hemoglobin	12.48		12.48	10.00
	Albumin	3.98		4.15	3.55
	Globulin	2.74		3.11	3.64
	Ca	10.4		10.4	10.4
	P	5.10		5.76	5.92
No. 9	Time	14 days		1½ hrs.	7 days
1st Lact.	Hemoglobin	9.68		10.75	8.47
	Albumin	4.15		4.02	4.02
	Globulin	2.40		2.42	2.72
	Ca	10.9		9.9	9.6
	P	5.22		4.04	6.22

TABLE 4

Analyses of normal cows' blood before and after calving for plasma phosphates and inorganic P and total Ca

Phosphatase = units of phosphatase as defined by Kay, 1930. Ca and P = mg. per 100 cc. of serum

COW NO. AND LACTATION	BEFORE CALVING							AFTER CALVING			
No. 12 3rd Lact.	Time				22 days	2 days		11 hrs.	5 days	8 days	22 days
	P 'tase				.086	.195		.200	.179		.106
	P				6.06	7.04		8.04		4.32	5.80
	Ca				9.8	9.6		8.9		10.2	10.3
No. 13 1st. Lact.	Time					2 days		8 hrs.	5 days	9 days	16 days
	P 'tase					.100		.106	.101	.172	.200
	P					6.81		7.88	2.80	5.62	
	Ca					10.9		10.9	10.7	11.1	
No. 14 4th Lact.	Time					12 days		11 hrs.	8 days	18 days	
	P 'tase					.0698		.163	.145	.090	
	P					9.12		4.40	5.72		
	Ca					10.2		9.0	10.0		
No. 15 2nd Lact.	Time					5 days		4 hrs.	9 days		
	P 'tase					.086		.238	.178		
	P					4.80		6.58	5.74		
	Ca					10.6		8.7	10.6		
No. 16 2nd Lact.	Time	16 days	8 days	6 days	4 days	2 days	2½ hrs.	6 hrs.	1 day	3 days	6 days
	P 'tase	.168	.110					.180			.097
	P		6.26	6.14	6.52	5.52	4.20	5.72	4.52	4.93	4.92
	Ca.		11.1	10.8	11.8	10.9	10.6	10.3	10.4	10.2	10.8
No. 18 2nd Lact.	Time					35 days	15 hrs.	1 day	3 days	5 days	10 days
	P 'tase					.225	.114	.097	.095		.085
	P						5.24	4.30	4.08	3.22	6.60
	Ca						9.4	8.3	9.2	8.5	9.2

TABLE 4—(*Continued*)

COW NO. AND LACTATION		BEFORE CALVING						AFTER CALVING			
No. 20 2nd Lact.	Time	40 days	9 days	7 days	5 days	3 days	2 hrs.	7 hrs.	1 day	4 days	19 days
	P'tase	.167	.103			.106		.193			.073
	P		5.44	4.96	4.88	5.40	5.42	6.82	6.08	5.06	6.42
	Ca		10.0	9.5	10.15	9.8	9.5	9.8	8.8	9.1	9.2
No. 21 1st Lact.	Time	31 days	11 days	9 days	6 days	4 days	20½ hrs.	1 day	3 days	14 days	
	P'tase	.189	.150					.168		.074	
	P		6.22	5.72	5.58	5.78	4.52	3.94	5.72	6.28	
	Ca		9.3	9.7	9.7	10.1	9.8	8.4	9.8	10.1	
No. 22 8th Lact.	Time	55 days	8 days	6 days	2 days	5½ hrs.		4 hrs.	2 days	5 days	9 days
	P'tase	.162	.059					.094			.099
	P			4.70	4.18	4.88		3.90	4.14	5.92	4.42
	Ca			10.4	10.1	9.2		9.5	8.3	8.8	9.3
No. 24 3rd Lact.	Time			46 days	9 days	2 days		8 hrs.	1 day	3 days	7 days
	P'tase			.214	.089				.228		.154
	P					5.54		6.86	6.10	6.10	5.54
	Ca					10.6		9.6	9.9	9.7	10.5
No. 25 1st Lact.	Time		42 days	11 days	2 days	16 hrs.		9 hrs.	1 day	4 days	11 days
	P'tase		.170	.110				.172			
	P			4.28	4.30	4.26		5.74	4.44	5.32	5.96
	Ca			9.4	10.5	9.0		10.1	8.95	10.2	10.5
No. 11 4th Lact.	Time					7 days		1 day	7 days		
	P'tase					.085		.095	.084		
No. 19	Time					29 days		1 day			
	P'tase					.182		.128			

TABLE 5

Phosphatase values obtained for the blood plasma and the milk of dairy cows

		PHOSPHATASE UNITS	
		Plasma	Milk
Cows near the end of lactation	1	.162	.838
	2	.094	.990
	3	.068	.637
Average		.108	.8217
Cows milking heavily	1	.090	.141
	2	.075	.083
	3	.097	.046
Average		.0873	.090

evident that the presence of this enzyme in the milk is not due entirely to simple diffusion from the blood plasma.

In addition to the work on the blood of cows in cases of normal calving, analyses were made on samples from a number of typical cases of milk fever and one case which was apparently on the verge of having the disease but did not come down with it. These results are shown in table 6.

In an endeavor to study how the blood Ca and P are regulated at the time of parturition, the udders of two young goats about 8 months old were removed. It was considered that analysis of blood samples of these goats near the time of parturition would show whether the blood is fortified in these two elements in order to compensate for the demand on them for milk fever. Porcher (23) had used this method in the study of sugar metabolism connected with milk secretion. Only one goat became pregnant and at the age of about 14 months she gave birth to one kid which was found dead. The blood analyses for this goat are shown in table 7. It will be seen that there was a decided increase in blood P after parturition, and that this high level of blood P was sustained for some time. The Ca level of the blood remained quite constant throughout.

DISCUSSION

The data on blood sugar show that the sugar was generally lower after normal calving than before. This is brought out in table 1. The difference between the averages before calving and after is not large, but 9 out of the 13 cases showed lower blood sugar after calving than before. There seems to be a tendency for the sugar to rise at or near calving time and then to fall later, and this may explain some of the higher sugar values obtained very shortly before calving. It was found that when samples were taken within 10 hours after calving and then again over 10 hours after, the sugar in the second samples after calving was appreciably lower than in the first

TABLE 6

Ca and P = mg. per 100 cc. serum; Sugar = mg. per 100 cc. blood; Hb = per cent hemoglobin in whole blood; Al and Gl = per cent albumin and globulin in serum; phosphatase = phosphatase units

CASE NO.	TIME	BLOOD CONSTITUENT					
		Ca	P	Total sugar	Hb	Al	Gl
I Typical of milk fever	Before inflation	4.6	1.36	144.9			
	14 hrs. after inflation	9.3	4.11	101.9			
	48 " " "	9.0	8.99	56.8			
	7 days " "	9.2	4.86	34.6			
II Typical of milk fever	Immediately after inflation	4.9	.56	74.6			
	19 hrs. after inflation	9.3	6.37	55.6			
	43 " " "	9.8	10.53	41.2			
	6 days " "	9.2	6.61	48.8			
	14 " " "	9.5	6.02	30.3			
III Typical of milk fever	Before inflation	3.8	2.96	186.0			
	1 hr. after inflation	4.0	5.32	157.8			
	4½ hrs. after inflation	6.9	5.62	76.9			
	3 days after inflation	10.3	10.23	54.3			
	9 " " "	11.0	4.73	46.2			
IV Apparently on verge of milk fever. Udder not inflated	4 hrs. before calving	9.2	less than 1	.....			
	5 " " "	7.1	less than 1	79.7			
	2 days " "	10.1	6.29	55.3			
V Typical of milk fever	15 hrs. before calving	10.6	4.96		12.8	3.77	2.26
	8½ hrs. after calving	6.0	1.52		13.6	4.15	2.40
	18 hrs. after calving, udder inflated	4.3	.88		13.5	3.96	2.12
	2½ hrs. after inflation	6.1	2.52		10.8	3.98	2.24
	1 day after inflation	7.8	5.82		10.8	3.94	2.14
	3 days " "	10.6	7.80		.....	3.74	2.34
	5 " " "	10.8	8.28		12.6	3.75	2.02
	11 " " "	8.4	4.24		9.8	3.98	2.38
VI Typical of milk fever	42 days before calving					Plasma Phosphatase .224	
	19 hrs. " "	10.0	3.86			.140	
	5 " after "	7.2	3.42			.175	
	29 " " "	5.1	2.44			.157	
	40 " " "						
	1 hr. after inflation	6.0	4.70				
	14 hrs. after inflation	7.7	6.40				
	2½ days after inflation	9.7	4.58				

samples, the averages being 91.2 mg. per 100 cc. for the first sample after calving and 59.9 mg. for the second. This is shown in table 2. Apparently some mechanism tends to increase the sugar of the blood at calving time in order to compensate for the drain on the blood for sugar used in the production of lactose, and to supply energy for milk secretion. This idea is in agreement with the results of Porcher (23) whose work has been men-

TABLE 7

Total Ca and inorganic P of the serum before and after parturition of a goat from which the udder had been removed

BEFORE PARTURITION					
TIME	25 days	12 days	9 days	5 days	1 day
Ca mg. per 100 cc.	10.2	10.6	10.8	11.5	10.9
P mg. per 100 cc.	7.66	9.32	7.28	6.94	5.98

AFTER PARTURITION				
TIME	1 day	3 days	11 days	20 days
Ca mg. per 100 cc.	10.3	11.5	10.9	11.3
P mg. per 100 cc.	11.52	9.36	10.26	7.68

tioned previously. In the milk fever cases for which blood sugar determinations were made a hyperglycemia was found. The results agree with those of Fish (5) and others. Apparently high blood sugar is a result of milk fever and not one of the causes of it.

The results given in table 3 show that the blood proteins may vary considerably—particularly the albumin and globulin. However, the variations do not occur in any very consistent manner. In 4 cases out of 8, Nos. 1, 2, 6, and 8, the albumin was higher near the time of calving than before or after this time. In 4 cases out of 7, Nos. 2, 5, 6, and 9, the hemoglobin was higher near the time of calving than before or after this time. In the other cases the changes in albumin or hemoglobin do not appear to be of any significance. The rise of hemoglobin and albumin that did occur at calving time in the above cases might be taken as evidence of a slight amount of anhydremia. The globulin did not show the same tendency to rise at calving as did the albumin and hemoglobin. Two cases out of the 8, Nos. 2 and 4 showed a higher globulin near calving than before or after, and two, Nos. 1 and 6 showed a lower globulin than before or after. In the other cases the changes in globulin are not considered significant. If globulin does go over from the blood into the colostrum milk as suggested by the work of Howe (15), the rate at which it goes over is apparently not rapid enough to affect the globulin level of the blood to any great extent.

Milk fever case No. 4 on which blood proteins were determined does not indicate any appreciable amount of anhydremia. Hemoglobin was a little higher 10 hours before the attack of milk fever and also at the time the cow was down with the disease than it was before or after these times, but the differences are not very great. It is true that there was some fall in hemoglobin after the udder was inflated and the cow had recovered, but the albumin and globulin were quite constant throughout. This case clearly indicates that anhydremia is not an important factor in milk fever, and

since the anhydremia theory is based essentially on indirect evidence it was not considered worth while to investigate it any further.

As stated previously the work done in the first part of this investigation did not show any consistent differences in the amounts of blood Ca or P before and after calving. However, the results of later work, in which more numerous samples were taken for each case, do bring out some interesting variations. These data, given in tables 3 and 4, show that there is a definite tendency for the Ca to fall shortly after calving particularly in cows which have been through one or more lactation periods. Every one of the ten cows which were not in their first lactation showed some fall in blood Ca some time during what is called the milk fever period. Of the 9 cows starting their first lactation only 5, Nos. 4, 6, 8, 21 and 25, showed such a fall in Ca. This is interesting when it is considered that milk fever rarely occurs at the first calving. In table 8 it is shown that the

TABLE 8

Average Ca and P values of normal cows' serum at different periods around the time of calving

	Total Ca Mg. per 100 cc.	Inorganic P Mg. per 100 cc.
Over 1 day before calving	10.560	5.772
Within one day of time of calving	9.855	5.373
Over three days after calving	10.390	5.521

average Ca value for all cows reported is lower within one day of calving than it is before this period. The differences between these averages is found to be a statistically significant one when the data are analyzed by Student's method. The average value for Ca after the milk fever period, or over three days afer calving, is slightly lower than the average before calving, but the difference is not a significant one.

The blood P likewise shows a tendency to fall at the milk fever period, but this tendency is not so constant for P as it is for Ca. Twelve cases out of 19 showed a fall in P, but only 6 out of the 10 cows not in their first lactation showed this effect. In general P values vary much more than the Ca values, the range obtained for apparently normal cows being from 9.12 to 2.80 mg. per 100 cc. for P and from 12.1 to 8.3 mg. per 100 cc. for Ca. In some cases there was quite a marked rise in P around the time of calving. Table 8 shows that the average P values for all cows reported is highest in the period over one day before calving and lowest at the period within one day of calving, but the differences between these averages cannot be considered significant.

The blood Ca and P values obtained on all five milk fever cases, vary in essentially the same way as those reported by Fish (5). The Ca and P are both low at the time of milk fever and both rise as a result of inflation.

The Ca gradually returns to normal, recovery taking place when the Ca value reaches 5 or 6 mg. per 100 cc. The P rises quite rapidly after inflation and reaches values decidedly above normal—later returning to the normal level. A hypercalcemia following udder inflation such as Dryerre and Greig (3) have reported was not detected in any of these 5 milk fever cases. This condition may have occurred in some of these cases, but at least it was not present at the time the samples obtained were taken.

Case No. 4 in which the cow was apparently on the verge of having milk fever but did not come down with it is quite interesting. The P in this case was very low—estimated at less than 1 mg. per 100 cc., both before and after calving. After calving the Ca dropped to 7.1 mg. per 100 cc. It seems probable that what milk fever symptoms were present in this case, were due to the low Ca, and that low P has little to do with causing the milk fever symptoms. Palmer, Cunningham and Eckles (21) report one case of normal calving where the P dropped to 1.67 mg. per 100 cc., 5 days after calving.

TABLE 9

Plasma phosphatase values obtained for normal cows at different periods before and after calving

Phosphatase values = units of phosphatase as defined by Kay

COW NO.	LACTATION	TIME BEFORE CALVING				TIME AFTER CALVING		
		55–21 days	20–11 days	10–5 days	4–0 days	0–4 days	5–10 days	11–22 days
11	4th				.085	.095	.084	
12	3rd	.087			.195	.200	.179	.106
13	1st				.100	.106	.101	.200
14	4th		.070		.163		.145	.090
15	2nd			.086		.238	.178	
16	2nd		.168	.110		.180	.097	
18	2nd	.225			.114	.097	.085	
19		.182				.128		
20	2nd	.167		.103	.106	.193		.073
21	1st	.189	.150			.168		.074
22	8th	.162		.059		.094	.099	
24	3rd	.214		.089		.228	.154	
25	1st	.170	.110			.172	.094	
Ave.		.1745	.1265	.0894	.1271	.1583	.1247	.1062

The results obtained on normal cows before and after calving do not give much indication as to how the levels of Ca and P in the blood are regulated around calving time. The data obtained on the goat, which are given in table 7, suggest that there may be some mechanism which fortifies

the blood in P in anticipation of the demand for it for lactation, but the blood Ca is apparently not influenced in this way. Greig (11) reports some data which indicate that whenever the blood Ca goes appreciably above or below normal, a reaction sets in which causes the Ca value to go in the opposite direction. No doubt the parathyroid glands would play an important rôle in such reactions. Gerschmann (8) has advanced the idea that there is a reciprocal relationship between the activity of the parathyroids and the blood Ca level. According to this idea when the blood Ca is low the parathyroids are stimulated to greater activity which tends to bring the Ca level up, and conversely, a high Ca level depresses parathyroid activity and this in turn tends to bring the Ca down. When we consider that the blood Ca is normally kept at a very constant level, it seems evident that it is controlled by some quite sensitive mechanism. Milk fever is essentially due to failure of the cow to maintain a sufficient amount of Ca in her blood. The abnormal drop in blood Ca, in milk fever, may be considered to result from one or both of the two following factors: first, an unusually large demand on the blood for Ca which the Ca regulating mechanism, though properly functioning, is unable to cope with; second, a failure of the Ca regulating mechanism to take care of the demand for Ca, which normally occurs at the onset of lactation. The first factor is probably the most important one.

The P value of the blood is quite markedly affected by various factors. This is brought out by the work of Palmer, Cunningham, and Eckles (21). Wide fluctuations in blood P can occur temporarily without causing any noticeable disturbances in the health of the animal. The low P values occurring in milk fever are probably the results of the conditions causing milk fever, and, apparently, low P has little to do with the etiology of the disease.

The data on plasma phosphatase before and after calving show considerable variation, but many cases vary in the same general way. There is a tendency for the phosphatase to be quite high, three weeks or more before calving, and then to gradually decrease till about the time of calving, when it goes up again. After calving it tends to gradually decrease again. However it is impossible to make any reliable interpretation of such data as our knowledge of phosphatase activity in the different tissues is quite limited. Interpretation is still more difficult on account of the fact that phosphatase in the plasma may be present as the result of a leakage or diffusion of this enzyme from various tissues of the body.

SUMMARY AND CONCLUSIONS

1. The blood protein values obtained in milk fever compared with those for normal calvings indicate that anhydremia is not an important factor in milk fever.

2. There is a tendency for the inorganic Ca of the blood of most dairy cows to fall slightly sometime within the first three days after calving. This tendency is most marked in cows that have been through a previous lactation period.

3. The inorganic P of the blood of dairy cows also tends to fall within the first three days after calving in many cases, but this tendency is not so consistent for P as it is for Ca. Blood P varies much more under the same conditions than blood Ca.

4. Additional evidence has been obtained that the essential factor in milk fever is a blood Ca deficiency.

5. Plasma phosphatase in dairy cows varies considerably. It tends to be fairly high three weeks or more before calving, then to fall till near the time of calving when it tends to go up. During the three weeks after calving it usually falls again.

6. The phosphatase activity of the milk is usually higher than that of the plasma of the cow, and the activity in the milk is much greater in cows at the end of lactation than in heavily producing cows at the beginning of lactation.

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ADDENDA

Since this paper was submitted for publication a paper has been published by Petersen, W. E., Hewitt, E. A., Boyd, W. L., and Brown, W. R., 1931, Jour. Am. Vet. Med. Assoc., LXXIX, 217; in which they describe the symptoms of hypoglycemia and hypocalcemia artificially induced in cows by the injection of insulin and sodium citrate solution respectively.

THE FAT PERCENTAGE OF MILK AS AFFECTED BY FEEDING MILK TO DAIRY COWS[1]

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INTRODUCTION

While the belief that feeds exert no specific influence upon the fat content of milk over long periods of time is generally accepted, the information in regard to the immediate effect of various feeds is somewhat conflicting. There seems to be reason for believing that certain feeds have a specific influence, for a short time at least, upon the fat percentage of the milk of cows to which they are fed. Such influence, if only of a temporary nature, is of little importance in its relationship to profitable production of butterfat. It is, however, a matter which is of considerable interest in its relation to the problem of milk secretion, and which may have some practical aspects in connection with the estimation of the yearly butterfat and milk production of individual cows under the systems of testing which are now in general use.

While many feeds have been studied in regard to their effect upon milk production and the composition of milk, no case has been found where dairy cows have been fed milk with the idea of determining its effect upon the composition of the milk produced.

REVIEW OF LITERATURE

The relation of feeds to butterfat percentage received much attention both in Europe and America during the last two decades of the nineteenth century and the first of the twentieth. Much of this work was not well controlled and in many cases involved small numbers of animals. While the results secured by different investigators often did not agree, there seems to be a general indication that certain feeds exert a specific influence upon the butterfat content of milk. This is particularly true of feeds of high fat content, and most notably of the oil bearing seeds and their products. The earlier American investigators rather consistently found the influence of feed to be of short duration and concluded that the effect was due to the change of feed rather than to any nutritional difference in the ration. This earlier work has been reviewed by Anderson (1) and by Clothier (5).

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[1] Published with the approval of the Director as Paper No. 1030, Journal Series, Minnesota Experiment Station.

Later investigators have uniformly found that feeds of high oil content such as flaxseed, peanuts, soy-beans, cottonseed meal, cocoanut meal and cocoa meal cause at least a temporary increase in fat percentage of milk.

Only one case was found where the effect of feeding milk was studied. Beger (3) using a sheep and a goat, found some indication that milk fat in the ration has a greater influence than other fats upon the fat percentage of milk. The following year Beger (4) made a more extensive study using three goats. His principal purpose was to study the relative effect of emulsified and non-emulsified fats in the feed upon milk production. He fed whole milk as a typical emulsified fat and skimmilk plus butterfat as a typical non-emulsified fat. Mixed feed with butterfat added was also fed to two of the animals, and in the case of the third, a period of mixed feed without butterfat and a period of skimmilk feeding were included. The two animals which had no periods without butterfat in the ration showed no variations between the different periods which could safely be attributed to the effect of the feed. The average fat percentage by periods of the third goat were as follows: whole milk, 3.75; skimmilk plus butterfat, 2.80; skimmilk, 2.45; mixed feed, 2.40; and whole milk, 3.25. The periods were of 10 to 12 days' duration with intermediate periods ranging from two weeks to two months in length. These results suggest that whole milk when given as a feed increased decidedly the fat content of this goat's milk while butterfat when fed with skimmilk had a similar effect but to a lesser degree. Skimmilk when fed alone apparently had no effect upon the fat percentage of the milk. Definite conclusions to this effect would not be justified since only one animal was involved.

EXPERIMENTAL

In a preliminary experiment, three Holstein-Friesian cows in the University herd, each producing about 40 pounds of milk daily, were fed whole milk with a fat content of about four per cent in amounts up to 36 pounds per day, in addition to their regular ration. None of the cows would drink liquid milk so it was necessary to add the milk to the dry grain ration. Some of the cows refused to eat the feed which was moistened with milk until a small amount of molasses was added to overcome the milk flavor. All attempts to teach cows to drink liquid milk were unsuccessful except in the case of those which were offered their own colostrum immediately after calving. Three cows were successfully taught to drink milk in this manner, although several refused. Of these three cows the one which apparently consumed the milk most readily suddenly refused to take the milk after it had been fed for nearly two weeks. Another of the three was removed from the herd because of disease. The third was fed thirty pounds of her own milk daily during alternate intervals and samples were tested from each milking. On the basis of observations made during these preliminary trials, an experiment was planned using eleven cows of three breeds and

in various stages of lactation. Due to the difficulty of getting cows to drink milk, and since it apparently has essentially the same effect when given in the feed as when given in liquid form, the milk was fed by mixing with the grain ration in the proportion of two pounds of milk for each pound of grain. During the control periods an equal amount of water was substituted for the milk. Following a six day preliminary period, the cows were divided into two groups. One group was fed the regular ration moistened with whole milk and molasses while the other was fed the regular ration moistened with water and molasses. The experiment was continued through three six day periods in this manner, the groups being reversed at the end of each period. The whole milk used was a mixture of Guernsey and Jersey milk with an average test of 5.4 per cent. Since we were primarily concerned with the immediate effect upon the fat content of the milk and the total fat yield, no attempt was made to equalize the feed intake to allow for differences in the plane of nutrition due to addition of milk or cream. During the fifth period, part of the cows from each group were given the regular ration moistened with skimmilk and molasses, while the remaining cows of each group were given the regular ration moistened with cream containing 40 per cent fat, diluted with water and molasses. One pound of cream was fed for each three pounds of dry grain mixture, the water being added in order that the liquid content of the feed might remain the same during the different periods. These groups were reversed during the sixth period.

TABLE 1

Breed and Stage of Lactation of Cows Used in Experiment and Amount of Whole Milk, Cream, and Skimmilk Fed Daily

COW NO.	BREED	MONTH OF LACTATION	MILK DAILY DURING WHOLE MILK PERIODS	SKIM DAILY DURING SKIM-MILK PERIOD	CREAM DAILY DURING CREAM PERIOD
			pounds	*pounds*	*pounds*
155	Jersey	Ninth	28	28	4⅔
160	Jersey	Fourteenth	20	20	3⅓
178	Jersey	Thirteenth	20	20	3⅓
382	Holstein	Third	40	40	6⅔
387	Holstein	Third	40	40	6⅔
388	Holstein	Fifth	40	40	5
403	Holstein	Fourth	40	40	6⅔
412	Holstein	Thirteenth	28	28	4⅔
542	Guernsey	Fifth	24	24	4
544	Guernsey	First	24	24	4
545	Guernsey	Fourth	28	28	4⅔

In addition to the grain, all of the cows were given all of the alfalfa hay and corn silage that they would clean up readily. The grain mixture consisted of 250 pounds each of corn, barley, and oats; 100 pounds each of bran and linseed meal; and 50 pounds of cottonseed meal. Dried beet pulp was added at the rate of one pound for each four pounds of grain to increase the absorptive powers of the grain mixture and to lighten the wet feed. The average daily fat percentage of the milk of each cow was found by applying the Babcock method to samples prepared by taking an aliquot part from both the morning and the evening milk.

Table 1 shows the breed and the stage of lactation of each cow and the amount of milk, skimmilk, and cream received daily during the respective periods in which each was fed.

OBSERVATIONS

A six day preliminary period was used for all the cows included in this experiment in order that they might become accustomed to the change from dry feed to wet feed, and to the addition of molasses and beet pulp to their ration. The change apparently had little effect upon the fat percentage of the milk, as the tests were very uniform during this period.

The first feed of milk was given to the group receiving milk at the last milking of the preliminary period. The change of feed was made thereafter for each group with the last milking of each period, since the earliest possible effect of this feed would be upon the morning milking of the following day. Upon the first day following the change little effect upon the fat percentage was noted. Upon the second day, a marked increase in fat percentage was observed for the cows receiving milk. Some of the cows showed a slight effect on the first day after the change. The preliminary trials in which each milking was tested separately indicated that no effect was usually observed previous to the milking occurring twenty four hours after the change. This higher test was maintained during the entire six day period. No similar increase was noted in the control group. The groups were reversed at the end of six days. Upon the second day following the reversal, the cows which had been on the milk feed and were changed to the control diet, dropped in test, while those which had been on the control diet and were changed to the milk diet showed a decided increase. The groups were again reversed with similar results. This lag or latent period following the addition of milk or cream and the residual effect when they were discontinued confirms the observations of Nevens, Alleman and Peck (8) and of Aplin and Ellenberger (2).

During the fifth and sixth periods, in order to find which part of the whole milk was responsible for this increase in fat percentage, skimmilk and cream were used in the manner previously indicated. The cream apparently affected the test in practically the same manner as the whole

TABLE 2

The Effect Upon Milk Production of Feeding Whole Milk, Cream, and Skimmilk

Average daily milk production by periods

COW NO.	PRELIMINARY	NO MILK	WHOLE MILK	CREAM	SKIMMILK
	pounds	*pounds*	*pounds*	*pounds*	*pounds*
Group I					
155	29.23	29.89	29.17	26.82	29.65
160	18.32	19.45	19.70	19.55	19.50
382	53.33	55.65	53.70	56.40	55.52
387	59.82	59.04	57.98	54.15	58.28
403	57.27	58.04	56.98	58.42	55.73
545	29.62	33.44	31.57	30.57	32.57
Average of group	*41.26*	*42.59*	*41.52*	*40.98*	*41.88*
Per cent above or below control	*−3.12*	*0.00*	*−2.51*	*−3.78*	*−1.67*
Group II					
178	15.15	15.70	16.35	15.35	16.17
388	50.83	51.72	48.83	42.25	44.27
412	34.07	32.85	35.13	31.30	34.48
542	22.03	23.33	25.10	21.47	23.85
544	28.30	27.78	28.06	26.38	26.03
Average of group	*30.08*	*30.28*	*30.70*	*27.35*	*28.96*
Per cent above or below control	*−0.66*	*0.00*	*+1.39*	*−9.68*	*−4.36*

TABLE 3

The Effect Upon Butterfat Production of Feeding Whole Milk, Cream, and Skimmilk

Average daily butterfat production by periods

COW NO.	PRELIMINARY	NO MILK	WHOLE MILK	CREAM	SKIMMILK
	pounds	*pounds*	*pounds*	*pounds*	*pounds*
Group I					
155	1.52	1.55	1.91	1.61	1.58
160	1.13	1.20	1.40	1.38	1.12
382	1.93	1.93	2.22	2.11	1.78
387	1.74	1.73	1.98	1.87	1.73
403	1.92	1.82	2.11	2.16	1.62
545	1.43	1.57	1.78	1.72	1.47
Average of group	*1.61*	*1.63*	*1.90*	*1.81*	*1.55*
Per cent above or below control	*−1.23*	*0.00*	*+16.56*	*+11.04*	*−4.91*
Group II					
178	1.02	1.02	1.23	1.13	1.00
388	1.67	1.75	1.76	1.56	1.47
412	1.50	1.41	1.70	1.44	1.44
542	1.06	1.07	1.30	1.10	1.08
544	1.53	1.42	1.62	1.45	1.22
Average of group	*1.36*	*1.33*	*1.52*	*1.34*	*1.24*
Per cent above or below control	*+2.26*	*0.00*	*+14.29*	*+0.75*	*−6.77*

milk, while the skimmilk periods gave in most cases the lowest tests of the entire trial.

Table 2 shows the average daily milk yield, table 3 the average daily butterfat production, and table 4 the average butterfat percentage by

TABLE 4

The Effect Upon Butterfat Percentage of Feeding Whole Milk, Cream, and Skimmilk

Average butterfat percentage by periods

COW NO.	PRELIMINARY	NO MILK	WHOLE MILK	CREAM	SKIMMILK
	per cent	*per cent*	*per cent*	*per cent*	*per cent*
Group I					
155	5.22	5.17	6.54	6.01	5.32
160	6.19	6.16	7.11	7.07	5.73
382	3.62	3.48	4.14	3.74	3.20
387	2.92	2.93	3.42	3.46	2.96
403	3.35	3.13	3.71	3.70	2.90
545	4.84	4.69	5.63	5.63	4.51
Mean of group	*4.36*	*4.26*	*5.09*	*4.94*	*4.10*
Per cent above or below control	*+2.35*	*0.00*	*+19.48*	*+15.96*	*−3.76*
Group II					
178	6.71	6.50	7.49	7.36	6.19
388	3.29	3.38	3.60	3.70	3.32
412	4.41	4.28	4.83	4.60	4.17
542	4.81	4.58	5.19	5.12	4.53
544	5.39	5.11	5.78	5.48	4.68
Mean of group	*4.92*	*4.77*	*5.38*	*5.25*	*4.58*
Per cent above or below control	*+3.14*	*0.00*	*+12.79*	*+10.06*	*−3.98*

periods for each cow. Since there seems to be a very definite tendency for the effect of each period to carry over until the second day following the change, it is thought that the true effect of the feed can best be shown by allowing for this lag in the effect. For this reason the averages given in these tables represent the period beginning with the second day following the change of feed, and including the first day following the succeeding change.

Chart I is a graph of the arithmetic mean of the daily fat percentages of each group during the whole milk and the control periods. Chart II is a similar graph for the cream and the skimmilk periods. The cows were grouped differently during the skimmilk and cream feeding periods because a part of the cows from each of the previous groups were changed to the skimmilk ration and a part were changed to the cream ration in order to show more clearly the constituent of the whole milk which was responsible for its effect.

No unfavorable physical effect which might be attributed to milk or cream feeding was observed even with the abrupt changes when these feeds

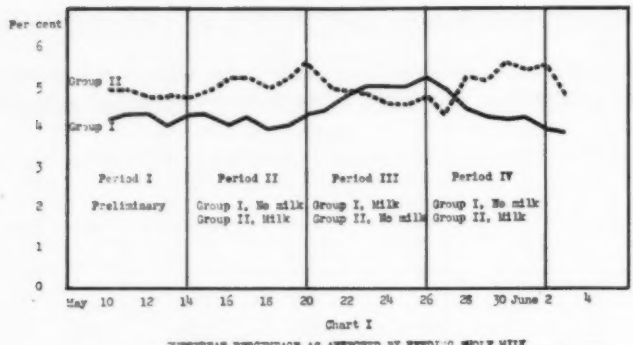

Chart I

BUTTERFAT PERCENTAGE AS AFFECTED BY FEEDING WHOLE MILK
(Group I, Cows 155, 160, 382, 387, 403, 545. Group II, Cows 178, 388, 412, 542, 544)

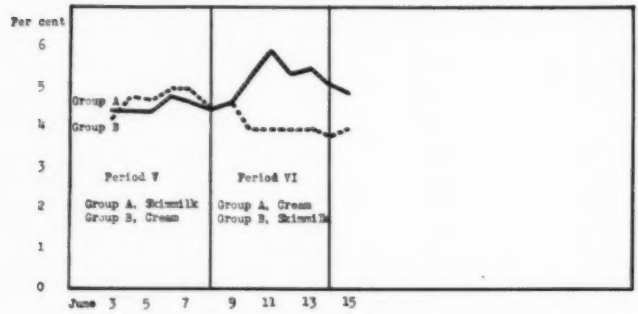

Chart II

BUTTERFAT PERCENTAGE AS AFFECTED BY FEEDING CREAM AND SKIMMILK
(Group A, Cows 155, 178, 387, 412, 542, 545. Group B, Cows 160, 382, 388, 403, 544)

were added. Two of the cows showed a slight diarrhea at a time when they were on the control ration while one similar case was noted in a cow receiving whole milk.

The objectionable taste of the milk is apparently associated with the butterfat, since none of the cows objected to the feed mixed with skimmilk. Cows number 542 and 544 were especially obstinate in their dislike for whole milk and cream. While they usually cleaned up all of their feed before the next milking, they were very slow in eating the feed mixed with whole milk or cream. In nosing around over the wet feed, they squeezed out a part of the liquid, and probably actually consumed less cream or milk on some days than is credited to them.

DISCUSSION OF RESULTS

The uniformity of these results would seem to show conclusively that feeding of whole milk or of cream to cows has a very decided tendency to increase the fat content of their milk during the period when fed. This

effect is brought about by an actual increase in fat production. While feeding of cream showed slightly less effect than whole milk upon fat yield and fat percentage, the individual results were not entirely uniform and it can not be stated definitely that this difference is characteristic of the two feeds. There seems to be little immediate effect upon milk production when whole milk is added to the ration of cows already being fed according to their requirements. With one group of cows the average milk production per period was greater during the period when milk was being fed, while in the other it was less. The milk production was lower during the cream feeding period for both groups as was indicated by the group averages, but the individual animals did not respond uniformly in this respect, as some of the cows had their highest milk production during the cream feeding period. The milk production during the skimmilk periods showed only slight variation from the control periods in which no milk was fed. The fact that cow number 388 was off feed during a part of the fourth and fifth periods and declined in milk production, has a tendency to decrease the average production of both milk and butterfat for Group II during the last three periods.

While the feeding of either whole milk or cream appears to bring about a marked increase in butterfat production and in butterfat percentage, skimmilk feeding gives no indication of increasing either of these factors. This indicates that the butterfat of the milk or cream or some constituent associated with the fat is responsible for the increased fat production and fat percentage.

The increase in fat production seems to be secured regardless of breed, stage of lactation, level of production, or condition of the cow. While the cows yielding milk with higher butterfat content showed a greater actual increase in test; if we consider this on the basis of the percentage of increase, there is not a large difference in the effect upon low testing and high testing cows.

The length of time for which milk feeding will continue to bring about increased fat production has not been determined. The cows which had a period of cream feeding immediately following a milk feeding period continued to produce a greater amount of fat than normal and to show a higher test for twelve days. In preliminary trials previous to this experiment, three Holstein cows showed a morked decrease in test of milk when milk feeding was discontinued after 16 days of feeding. Cow 388 of this experiment had previously been given 30 pounds of her own milk daily over two-week periods, and showed a decline in fat percentage each time the milk was discontinued, with a corresponding increase when milk feeding was resumed. Even though this effect may not be permanent, it might become a factor of practical importance in testing for butterfat production.

It is clear that the results of milk feeding can not be attributed to the change in plane of nutrition since the effects are not in line with those which we might expect from this factor alone. Eckles (6) has shown that when the plane of nutrition is lowered with cows in high condition, an increase in fat content of the milk usually results. Most of the cows of this group were in good condition, while some were in a high condition of fleshing. The lowering of the plane of nutrition when milk feeding was discontinued would be expected on the basis of the observations of Eckles to have a tendency to bring about an increase in fat content of the milk produced, which is entirely contrary to the results secured. Eckles and Palmer (7) found no significant effect on fat content of cows' milk due to an increase in the plane of nutrition.

The fact that the fat production and fat percentage merely returned to normal during the control periods and were not depressed to a subnormal level suggests that the effect of feeding butterfat in the form of whole milk or cream is probably a nutritional rather than a stimulative one.

The feeding of whole milk or cream to cows is a very inefficient method of increasing butterfat production as the increase in butterfat secured accounted for less than twenty per cent of the butterfat consumed by the cows.

SUMMARY

1. When whole milk was fed during alternate six-day periods to eleven cows in various stages of lactation, in addition to their regular ration, a marked increase in butterfat percentage and butterfat production resulted. This effect first became apparent about twenty-four hours after the milk was added and was maintained for an equal length of time after it was discontinued.

2. Similar results were obtained by feeding cream of high fat content.

3. The increased butterfat production secured by feeding whole milk or cream may be maintained for at least twelve days.

4. Skimmilk feeding did not bring about an increase in either butterfat production or butterfat percentage.

5. Definite conclusions in regard to the effect of milk feeding upon the milk production as shown by this experiment are not justified since the response of the different animals was not uniform. The results suggest that the immediate effect upon milk production is not significant.

6. The additional butterfat production due to feeding whole milk or cream was secured in a very inefficient manner, since the increase accounted for less than twenty per cent of the butterfat consumed.

7. Milk was not readily consumed by cows which were not accustomed to it, either as a drink or when mixed with their grain feed. Most cows, after becoming accustomed to the taste of milk, ate it readily when mixed

with feed. Some cows which had been taught to drink milk consumed the liquid milk readily.

8. No unfavorable physiological effect was observed in cows fed up to forty pounds of milk containing over two pounds of butterfat daily, even when added to the ration in the full amount after a period in which no milk was fed.

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CONTROL OF SPREADERS IN MILK PLATES[1]

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Our interest in the problem of the control of spreaders in milk plates was aroused by the occasional difficulties experienced in various milk laboratories. The problem was attacked from the point of the probable effect of differences in humidity in the air inside the agar plates, such as might occur with differences in the concentration of the agar used for the plates. A batch of 1.5 per cent agar was tubed and divided into five parts, which were subjected, respectively, to the various rates of drying which would occur in such places as a laboratory shelf, an incubator, an ice-box, a shelf over a radiator, and a closed tin receptacle, for a period of one week. When this agar was inoculated with spreaders and plated, the driest agar gave most definite evidence of the inhibition of the spreading tendency.

Thereupon, three different percentages of agar were prepared, with a still wider range in the relative agar-water content: 1.5, 2, and 3 per cent, according to the following proportions.

For every 1,000 cc. of tap water
3 grams Vegex.
5 grams Bacto-Peptone.
15, 20, and 30 grams of agar for the respective types of agar.

Each mixture was melted in an autoclave and filtered through a wet, hot, absorbent cotton filter; it was then tubed, exactly 10 cc. to a tube, and sterilized 30 minutes in the autoclave at 15 pounds pressure.

These three known concentrations of agar were then used in plating milk inoculated with one or more of a series of 12 different spreading organisms, obtained from recent routine milk plates in a large commercial plant. Raw, pasteurized, and sterile milk were used, also aged raw milk (4 days old); each lot of milk was inoculated with 1 cc. of a milk dilution of one or more spreaders, as indicated in Table 1.

The characteristic differences obtained with the three concentrations of agar are illustrated by the accompanying photographs; and the degree of spreading (number of spreaders and diffusion over the plate) is indicated in the table by * signs, ranging from *, indicating slight spreading, or 1–5 spreading colonies only to a plate, to *****, as in the 1½ per cent agar plates in figures 2 and 3.

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TABLE 1

Degrees of spreading with total colony counts on 1½, 2 and 3% agar

INOCULATIONS	DILUTIONS	DEGREE OF SPREADING			COLONY COUNT		
		1½%	2%	3%	1½%	2%	3%
1. Agar, Spr. 1	10,000	*****	**	0	———	———	———
	100,000	***	***	0	28,600,000	28,080,000	30,000,000
2. " " 2	10,000	*****	**	0	———	———	———
	100,000	****	***	0	920,000	900,000	1,500,000
3. Milk (sterile), Spr. 4	1,000	**	**	*	———	16,000	24,000
4. " Spr. 5		**	**	*	64,000	68,000	67,000
5. " " 6		**	**	*	12,000	11,000	13,000
6. " (fresh, raw), Spr. 1	1,000	**	*	0	121,000	131,000	110,000
7. " Spr. 2	"	**	0	0	14,000	7,000	3,000
8. " " 3	"	**	0	0	26,000	10,000	14,000
9. " " 4	"	**	**	*	4,000	8,000	7,000
10. " " 5	"	***	**	*	34,000	32,000	25,000
11. " " 6	"	*	0	0	1,860,000	1,380,000	1,296,000
12. " " 4, 5, 6	"	*	0	0	1,662,000	1,860,000	1,800,000
13. " " 7	"	*	*	0	54,000	53,000	54,000
14. " " 8	"	**	*	0	53,000	74,000	45,000
15. " " 9	"	0	0	0	132,000	142,000	115,000
16. " " 10	"	0	0	0	220,000	210,000	198,000
17. " " 11	"	**	0	0	200,000	400,000	180,000
18. " " 12	"	**	*	*	75,000	110,000	68,000
19. " " 1	10,000	*	0	0	20,000	80,000	30,000
20. " " 2	"	0	*	0	600,000	530,000	540,000
21. " " 3	"	*	0	0	40,000	60,000	———
22. " " 1, 2, 3 and *coli*	"	*	0	0	2,940,000	2,880,000	3,360,000
23. " *coli* only	"	—	—	—	6,480,000	11,880,000	9,240,000
24. " (4 days old), Spr. 1	1,000	*	*	0	5,040,000	6,720,000	3,060,000
25. " Spr. 2	"	***	**	0	1,440,000	2,040,000	2,580,000
26. " " 3	"	*	0	0	7,080,000	3,000,000	4,020,000
27. " " *coli*	"	—	—	—	2,940,000	2,880,000	3,360,000
28. " " 1, 2, 3 and *coli*	"	**	*	0	3,840,000	2,880,000	2,440,000
29. " " 4	"	**	**	1	20,000	22,000	22,000
30. " " 5	"	**	*	0	87,000	170,000	210,000
31. " " 6	"	**	*	0	51,000	53,000	47,000
32. " " 4, 5, 6	"	*	*	0	30,000	85,000	107,000

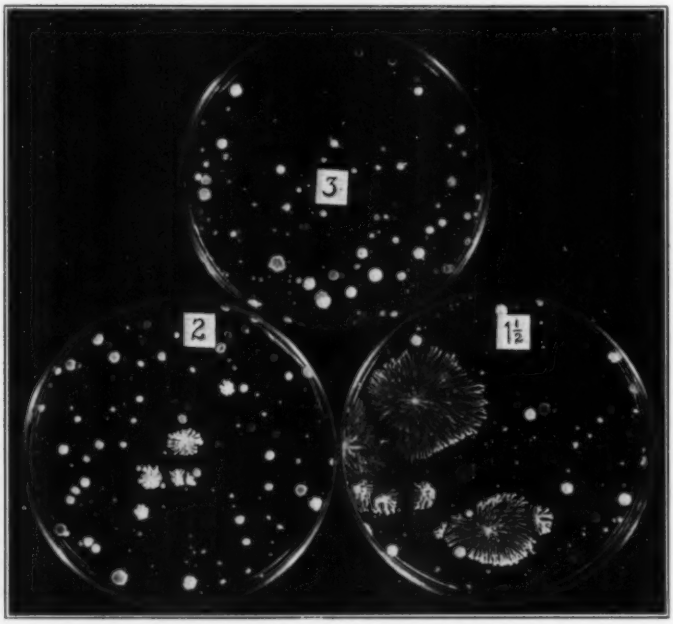

FIG. 1. TYPICAL RANGE IN BRANCHING, SPREADING COLONIES OBTAINED AFTER INCUBATION FOR 2 DAYS WITH 1½, 2, AND 3% AGAR

A high bacterial content was characteristic of most of the samples of milk used, and dilutions of 1,000 and 10,000 were usually used in making the plates; in a few cases 100,000 was also used. The weakest dilution is usually the one recorded in table 1. The more crowded of the high dilution plates were counted with the lantern-mirror device described by Broadhurst and Brown[2] which makes it possible to count crowded plates with a high degree of accuracy.

The total counts are, of course, important in this connection, since any medium which reduced the count per c.c. would give an erroneous report of the milk. The total colony counts are, therefore, given with the "spreader" reports in table 1.

To determine whether or not the higher concentrations of agar would limit the development of pin point colonies, which would militate against its use in milk examination, pin point organisms, obtained in a recent dairy laboratory outbreak, were used to inoculate milk (sterile and raw) rather heavily. As shown by the pin point results in table 2, pin point colonies develop about as readily in the 3 per cent agar as in the weaker concentrations.

[2] Abstracts of Bacteriology, p. 10, January, 1925.

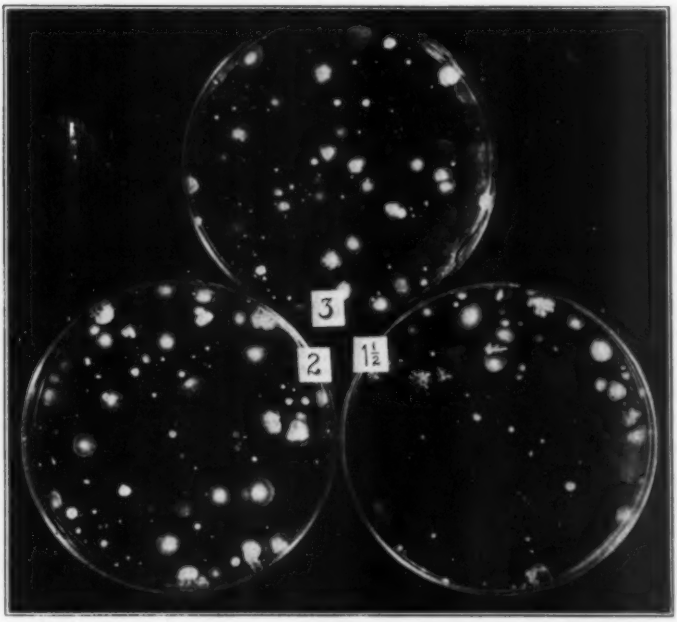

FIG. 2. TYPICAL RANGE IN DIFFUSE TYPE OF SPREADERS OBTAINED AFTER INCUBATION FOR 2 DAYS WITH 1½, 2, AND 3% AGAR. (THE PHOTOGRAPHY WAS DELAYED FOR TWO DAYS, DURING WHICH THE SLIGHT CRACKING NOTICEABLE IN 2 AND 3 OCCURRED.)

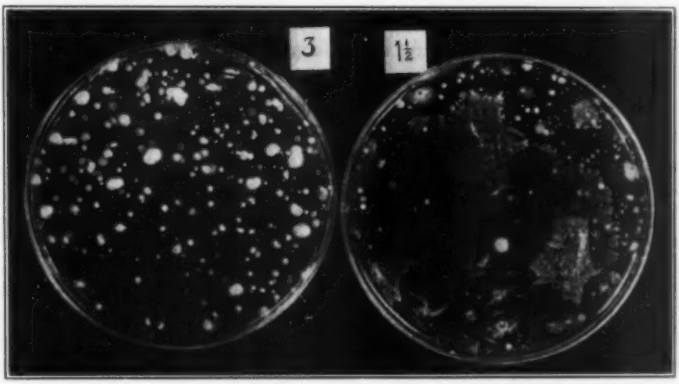

FIG. 3. TYPICAL RANGE WITH MIXED SPREADERS (CONDITIONS AS IN FIG. 2)

TABLE 2

Pin point and total colony counts in 1½, 2 and 3% agar

INOCULATION OF PIN POINT CULTURE INTO		DILUTION	1½%		2%		3%	
			Pin point	Total	Pin point	Total	Pin point	Total
Milk (sterile)	1	1,000	32		78		17	
"	2	"	110		100		370	
"	3	"	51,300		25,820		——	
"	4	"	1,140,000		1,170,000		1,098,000	
Milk (raw)	5	100	172,000	179,700	90,900	98,000	95,400	106,600
"	6	"	245,700	260,400	234,000	249,300	253,800	278,000
"	7	"	385,200	395,000	419,400	435,600	312,200	357,800
"	8	"	198,000	235,200	181,000	219,600	179,400	247,800
"	9	"	108,600	114,000	270,600	277,700	300,000	329,600

Since the total count and the pin point count are not reduced by the use of 3 per cent agar, it can be recommended for routine milk examination as a medium which will limit the development of spreaders[3] without giving a false idea of the bacterial content of the milk.

If the higher 3 per cent agar is not used to replace entirely the 1.5 per cent agar in routine plating of milk, it could advantageously be used to make a duplicate plate for the weakest dilution, thus insuring a countable plate should spreaders give trouble on the ordinary agar.

CONCLUSIONS

1. The development of spreaders may be controlled by using higher concentrations of agar. The 2 per cent agar is not sufficiently helpful in reducing spreaders to recommend its adoption; but the 3 per cent agar causes a marked reduction in the spreaders.

2. The total bacterial count is not markedly or uniformly reduced by the 3 per cent agar.

3. The use of 3 per cent agar does not interfere with the development of pin point colonies.

[3] Since the completion of this work (July, 1930, to April, 1931) the investigations of Boerner and Robinson on the Factors Influencing the Prevalence of Spreaders on Agar Plates in Bacteriologic Examination of Milk has appeared in the *Journal of Infectious Disease*, for April, 1931. The experiments described by these workers eliminated the various environmental factors in the laboratory as sources of spreaders, thus relating the presence of spreaders to the milk itself and the pre-laboratory conditions. Their results lead them to conclude that spreaders are inhibited by using limited amounts of agar in the plates—10 c.c., rather than 15 c.c. or 20 c.c. Spreading was also affected by the use of a dehydrating agent (calcium chloride) in the incubator, which changed the agar concentration from 1½ to 2½ per cent. There is some parallelism in their results and ours, as we find that spreaders are less in the more concentrated agar plates. Our work, however, was all done with carefully measured 10 c.c. amounts, and contrary to their reports, spreaders can develop luxuriantly on 10 c.c. plates, as illustrated by our photographs.

SOME FACTORS INFLUENCING THE CAPACITY OF THE ATMOSPHERIC DRUM DRIER

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Dry milk prepared by the atmospheric drum process in American plants was at one time considered suitable only for stock food. During recent years there has been a growing tendency to dry milk, principally skimmilk and sweet cream buttermilk by this process for human consumption.

Though dry milk made by the spray process is more completely redispersed into water than that made by the atmospheric drum process, little or no evidence is available which would indicate that this property of dry milk is of any great importance to the present users of the product. True, if dry milk is to be reconstituted and sold as fluid milk the product made by the spray process would need be used; however very little, if any, market milk is now being prepared from the dry product nor is likely to be prepared in the near future. It is likely, therefore, and quite logical that greater uses will be found in the future for drum process dry milks such as dried skimmilk and sweet cream buttermilk.

Much work has been conducted in studying the physical and chemical properties of dry milks. Considerable attention has been given by investigators to the keeping qualities, degree of dispersion in aqueous solution, manufacturing procedures effecting the dispersion, and to the cause and prevention of dry milk defects. By far the greatest amount of this work has been conducted with dry milks made by the spray process.

Little or no work is found in the literature on the operation of the drum drier. Information now available on the operation of such machines is to be found in publications issued by the manufacturers interested in the sale and distribution of drum driers. It was the object of the work here reported to study a few of the possible factors influencing the capacity of the drum drier. The work was prompted on interviewing a number of operators of the drum drier, from whom it was learned that little or no uniformity existed in the procedure of operation. It was observed that in some plants cold milk was passed on to the hot drums, while in others the milk was preheated to varying temperatures and passed on to the drums in a hot state. It was this fact, primarily, that induced the writers to consider the subject of the factors influencing the capacity of atmospheric drum driers.

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[1] Paper No. 1035, Journal Series, Minnesota Agricultural Experiment Station. The data here presented constitute a portion of those assembled in the thesis of E. H. Hubbard, submitted in partial fulfillment for the degree of Master of Science, University of Minnesota, June, 1930.

EXPERIMENTAL

A number of the possible factors influencing the capacity of an atmospheric double drum drier were considered. The following factors were included in the work here presented.

1. Temperature of milk when applied to the drums.
2. Amount of milk over drums—referred to as the "milk level" and indicated as "low," "high," and "normal."
3. Steam pressure and speed of drums.
4. Concentrated milk.

Skimmilk was dried on an atmospheric double drum drier manufactured by the Buffalo Foundry and Machine Company. The size of the drums was 24″ x 36″, rated with a capacity of 40 pounds per hour when skimmilk is dried and 90 pounds per hour when concentrated skimmilk of 25 per cent solids is dried.

Fresh skimmilk of a titratable acidity of not to exceed 0.2 per cent was pasteurized at 145° F. for 30 minutes and cooled to below 50° F., at which temperature the milk was held until desiccated. From 600 to 1000 pounds of skimmilk were used with each trial containing a representative solid content for the Twin City area of 9.2[2] per cent solids. Concentrated skimmilk containing 30 per cent milk solids was desiccated in determining the influence of this type of milk on capacity of the drier.

A standard method of drying milk on the drum drier was adopted as follows: Milk was preheated to a temperature of 150 to 160° F. and passed on to the hot drums. The milk was maintained at a level over the drums to a point just below the bottom of the splash plates and even with the top of the drums. A steam pressure of 60 pounds was used on the drums at a speed of 24 r. p. m. The capacity of the machine under these conditions was found to be about 58 to 60 pounds per hour. This capacity is well above the rated capacity of the machine, probably due to the slight increase in speed used over that recommended by the manufacturer.

The drums were put into motion after which the steam was turned on slightly and gradually increased until the steam gage recorded 60 pounds. The drums were then allowed to heat for 10 to 15 minutes after which the knives were adjusted and milk allowed to flow on the drums. After the machine had been in operation for some time the capacity study was conducted. Particular care was taken to make changes in operating conditions slowly. The capacity of the machine under a given condition was then determined by weighing the dry milk produced in a given time.

The moisture content of dry milks produced in a number of instances was determined using the method suggested by Bidwell and Sterling.[3]

[2] Composition of skimmilk for the Twin City area will average 9.2 per cent total solids during the winter and 9 per cent during the spring and summer months.

[3] Bidwell, C. L., and Sterling, W. F. 1925. Preliminary notes on the direct determination of moisture. Indus. and Engin. Chem. 17: 147.

Solubility determinations were made on these samples using a modification of the method used by Supplee.[4] The method followed consisted in agitating 20 grams of the dry milk with 200 cc. of distilled water at room temperature for 15 minutes. A 50 cc. portion of the reconstituted milk was transferred to a centrifugal tube and centrifuged at 1000 r. p. m. for 15 minutes. A total solids determination was then made on a 2 gram sample of the supernatant liquid. The solubility was then expressed in percentage of moisture free dry milk dispersed in the supernatant liquid.

Influence of Temperature of Milk on Capacity of the Drum Drier

Skimmilk of varying temperatures, ranging from a cold state (50 to 60° F.) to 185° F. was applied to the drums operated under standard conditions. The results are shown in table 1. Operation of the drier under

TABLE 1

The Influence of the Temperature of Skimmilk when applied to the Drums on the Capacity of the Atmospheric Drum Drier

TRIAL NO.	TEMPERATURE OF MILK WHEN APPLIED TO DRUMS	DRY SKIMMILK PRODUCED	TIME TO DESICCATE	CAPACITY PER HOUR
	°F.	pounds	minutes	pounds
1	50–60	40.00	45	53.0
2	50–60	15.00	17	53.0
3	125	9.25	10	55.5
4	155	32.00	33	58.0
5	160	18.5	19	58.0
6	175	39.0	35	67.0
7	185	15.0	13	69.0

standard conditions, which included applying the milk to the drier at 155° F., resulted in the production of 58 pounds of dry skimmilk per hour. Cold skimmilk applied to the drum resulted in a capacity of 53 pounds per hour, a reduction of 5 pounds, or 8 per cent. By heating skimmilk to 175° F. before applying to the drums, a production of 67 pounds of dry skimmilk per hour, or an increase of 15.5 per cent over the capacity of the drier when skimmilk was applied at 155° to 160° F., was obtained. A capacity of 69 pounds of dry skimmilk per hour was secured when the skimmilk was applied on the drums at 185° F., or an increase of 18 per cent when compared with the capacity secured under standard operation.

The significant data here presented, were the striking differences in the capacity of the atmospheric drier when milk at a low temperature (50 to 60° F.) was applied to the drums as compared with the capacity of the machine when milk was heated to 175 to 185° F. previous to drying. There was an increase of 26 to 28 per cent due to applying the hot milk on the drums as compared with cold milk.

[4] Supplee, G. C., and Bellis, B. 1925. Jour. Dairy Sci. 7: 39–46.

The Effect of the Milk Level over the Drums on the Capacity of the Drum Drier

The level of milk over the drums was varied to a point well below and above that used under standard operation. The influence of a reduced and increased milk level on the capacity of the drier is shown in table 2.

TABLE 2

The Influence of the Milk Level over the Drums of the Capacity of the Atmospheric Drum Drier

TRIAL NO.	MILK LEVEL	AMOUNT OF DRY MILK	TIME REQUIRED TO DESICCATE	CAPACITY PER HOUR
		pounds	minutes	
1	Low	17.25	21.0	49
	Normal	32.00	33.0	58
	High	16.25	13.5	72
2	Low	13.00	24.0	32
	Normal	13.50	17.0	47
	High	15.00	14.0	64

The results show conclusively that when the drier was operated with a low level of milk over the drums the capacity of the machines was greatly reduced. Likewise, an increase in capacity is secured by increasing the level of milk well above the drums. The low capacities reported on the batches of skimmilk dried in trial 2 are due to the difficulty experienced of establishing the normal level. The results of the two trials, however, are well in accord.

In comparing the capacity of the machine at different milk levels, it is observed that an increase of 40 pounds per hour, or 80 per cent, was secured when a high level was used in trial 1 as compared with the result secured in trial 2 when a low milk level was used on the drums. For maximum capacity, the milk should be held at as high a level as possible and yet avoid spillage.

Influence of High Steam Pressure and High Speed of Drums on Capacity of Drier

Some difficulty was experienced in attempting to vary the speed of the drums and the steam pressure at the same time when skimmilk was dried. When a high speed was attempted with a low steam pressure the resulting film became too wet or rolled at the knives. Since it was found that when skimmilk is dried a radical change in speed required a similar change in steam pressure it was deemed advisable to combine the two factors as one. The drier was operated at the standard speed and steam pressure and at a speed of 36 r. p. m. and with 85 pounds steam pressure on the drums. Milk was applied on the drums in a cold state, at 155° F. and 185° F. The influence of this procedure on the capacity of the drier is shown in table 3.

TABLE 3

Influence of Steam Pressure and Speed of Drums on the Capacity of the Drum Drier

TRIAL	TEMPERATURE OF MILK	STEAM PRESSURE	SPEED OF DRUMS	AMOUNT OF DRY MILK PRODUCED	TIME REQUIRED TO DESICCATE	CAPACITY PER HOUR
	°F.	pounds	r. p. m.	pounds	minutes	pounds
1	50 to 60	60	24	40.0	45	53.0
	50 to 60	85	36	16.0	15	64.0
2	155	60	24	32.0	33	58.0
	155	85	36	14.5	12	72.5
3	185	60	24	15.0	13	69.0
	185	85	36	17.0	12	85.0

It is evident from the data secured that regardless of the temperature at which milk is applied to the drums an increase in the steam pressure and speed of the machine resulted in an increased capacity. The maximum capacity was secured when skimmilk was preheated to 185° F. and the machine operated at a speed of 36 r. p. m. and a steam pressure of 85 pounds used on the drums. It is apparent that when efficient operation is desired, high milk temperatures should be accompanied with increased speed and temperature of drums.

The capacity of the machine when cold milk was applied to the drums and operated at 24 r. p. m. using 60 pounds of steam pressure in the drums was 53 pounds per hour. An increase of 32 pounds per hour, or 60 per cent, was secured by preheating the milk to 185° F. and operating the machine at 36 r. p. m. and using 85 pounds steam pressure in the drums.

The Influence of Drying Concentrated Skimmilk on the Capacity of the Atmospheric Drier

It is conceded that the most efficient means of removing the water of milk is by boiling milk under vacuum. Though it is known in a general way that the capacity of the drier can be increased by precondensing before drying on the atmospheric drum drier, no experimental data are available on the subject. Concentrated milk at 40° F. was applied to the drums of the drier.[5] The speed of the drums was 34 r. p. m. in the trial made using cold concentrated milk and from 20 to 36 r. p. m. with concentrated milk at 180° F. The data secured are shown in table 4.

The most striking result of this experiment was the capacity of the drier when concentrated milk was heated to 180° F. and passed on the drums operated at 36 r. p. m. (trial 5). In this instance, the capacity reached 130 pounds of dry skimmilk per hour. Of interest, also, was the capacity of the drier of 70.2 pounds per hour when cold (40° F.) concentrated milk (trial

[5] The drying of the milk in this trial was supervised by S. T. Coulter of the Division of Dairy Husbandry of the University of Minnesota.

TABLE 4

The Capacity of the Atmospheric Drum Drier as Influenced by Concentrated Milk

Concentrated milk applied to drums at 40° F. and 180° F. Steam pressure on drums 80 to 85 pounds. Speed of drums varying from 20 to 36 r. p. m. Concentrated milk containing 30 per cent total solids.

TRIAL NO.	TEMPERATURE OF MILK	SPEED OF DRUMS	DRY MILK PRODUCED	TIME REQUIRED TO DESICCATE	CAPACITY PER HOUR
	°F.	r. p. m.	pounds	minutes	pounds
1	40	34	21.0	18	70.2
2	180	20	50.0	41	73.2
3	180	28	82.0	49	100.0
4	180	34	10.5	6	105.0
5	180	36	74.0	34	130.0

1) was applied to the drums when operated at 34 r. p. m. and the capacity of 73.2 pounds per hour when concentrated milk at 180° F. was passed on the drums operated at a speed of 20 r. p. m. The influence of the speed of drums on the capacity of the drier was secured with less difficulty when concentrated milk was used by operating the drier with 80 to 85 pounds steam pressure than was experienced in the case of skimmilk. In trials 2, 3, 4, and 5, the speed of the drums was 20, 28, 34, and 36 r. p. m. respectively. The capacity of the drier was increased from 73.2 pounds of dry milk per hour when operated at a speed of 20 r. p. m. to 130 pounds per hour when operated at 36 r. p. m.

Other Factors Influencing the Capacity of the Atmospheric Drum Drier

The experience gained in the work here reported suggested to the authors a number of other factors which may possibly influence the capacity of such machines as the atmospheric drum wrier. Though no data are here presented, it is the belief of the writers that atmospheric conditions, particularly temperature and humidity, are important factors affecting the capacity of such machines as they are in the case of spray drying machines. The velocity of the air over the rolls doubtless affects the capacity of the drier as well as its utilization of steam. In the conduction of the work here reported no attempt was made to control the temperature, humidity, or velocity of air coming in contact with the drum drier. It is felt in some instances that the above conditions influenced data on some factors studied but not here reported and on which further work will need to be completed.

Solubility and Moisture as Effected by the Rate of Drying Milk on the Atmospheric Drum Drier

The evidence presented above indicates quite clearly that there may be a wide variation in the rate at which dry milk is produced on the atmospheric drum drier. The question naturally arises, is the increased capacity accom-

plished at the expense of increased moisture in the finished dry milk and is the solubility of the dry milk affected? Since the moisture and solubility determinations were not made on all samples, the determinations presented in table 5 represent occasional samples from the trials conducted on the

TABLE 5

Relation of Amount of Dry Milk Produced per hour on the Drum Drier to the Moisture Content and Solubility of Dry Skimmilk

SAMPLE	DRY MILK PRODUCED PER HOUR (CAPACITY)	MOISTURE	SOLUBILITY
	pounds	per cent	per cent
1	49	3.6	72
2	58	3.6	72
3	64	3.2	71
4	70	3.7	73
5	72	4.2	71
6	72	3.2	72
7	85	3.8	72
8	100	3.0	72
9	105	3.2	72
10	130	3.4	72

effect of milk level, influence of high steam pressure and high speed, and the influence of drying concentrated skimmilk on the capacity of the drier. It will be observed from the data presented that when the drier was operated under conditions which result in an increased capacity of the machine that there was no effect on the moisture content of the resulting dry milk. It was further observed that the solubility of the dry milk was in no way influenced due to varying rates or drying. This statement however does not include conditions of drying which may have resulted in an excessively dry film near the knife nor conditions which encouraged the production of burnt milk on the roll.

SUMMARY

Some of the possible factors responsible for variations in the capacity of atmospheric drum driers are suggested. A standardized method of procedure was set forth for the operation of the drier. The influence on the capacity of the drier on variations from this procedure are reported. Under standardized or normal operation it was stated that the capacity of the drier was from 58 to 60 pounds per hour. Drying of cold milk (50 to 60° F.) resulted in a decrease of 8 per cent in the capacity of the machine. By preheating skimmilk to 185° F., an increase in the capacity of the machine of 18 per cent was secured. It was noted that 26 to 28 per cent more dry skimmilk resulted per hour when skimmilk was applied to the drums at 180 to 185° F. than when skimmilk was applied on the machine in a cold (50 to 60° F.) state.

The level at which the skimmilk is maintained over the drums was shown to materially affect the capacity of the drier. In one instance the capacity of the machine was reduced to 32 pounds per hour when a low level was maintained, and in another, when a high level was used, there was a yield of 72 pounds of dry skimmilk per hour, a difference of 40 pounds per hour.

The influence on capacity of the steam pressure in the drums and the speed of the machine was studied. With an increase in speed of drums to 36 r. p. m. and an increase in steam pressure in the drums to 85 pounds, the capacity of the machine was 85 pounds of dry skimmilk per hour. Regardless of the temperature of the milk when applied to the drums, the increased speed and steam pressure resulted in increased capacity of the machine. The greatest capacity was secured, however, when the temperature of the milk was applied at the higher temperature (185° F.) using a high speed of machine and high (85 pounds) steam pressure.

The most marked influence on the capacity of the drier was noted when concentrated skimmilk containing 30 per cent solids was dried. When cold (40° F.) concentrated skimmilk was applied to the drums operated at 34 r. p. m. a capacity of 70.2 pounds of dry skimmilk per hour resulted. By reducing the speed of the machine to 20 r. p. m. and applying milk at 180° F. to the drums, a capacity of but 73.2 pounds of dry skimmilk resulted. By using the same steam pressure, increased speed of drums up to 36 r. p. m., and applying concentrated milk at 180° F., the capacity of the machine was increased to 130 pounds per hour, or 116 per cent increase over that secured under the standardized method adopted.

Though some variation was observed in the moisture content of dry milks produced on the drum drier, it was not possible to correlate variations in moisture of dry milk with the rate at which dry milk was produced from the dryer. With milk of uniform freshness it was evident that variance of the capacity of the drier had no effect on the amount of dispersion of dry milk when reconstituted with water.

Conclusions

The capacity of atmospheric drum driers is influenced by the following conditions:

1. Concentration of milk.
2. Temperature of milk.
3. Steam pressure used in drums.
4. Speed of drums.
5. Level at which milk is maintained over drums.

CHEESE SPREADS[1]

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The term cheese spread may be applied to any form of packaged cheese that is of such consistency that at ordinary room temperature it may easily be spread with a knife. There are several types of such products on the market:—(1) Cream cheese with pickles, olives, et cetera added, (2) processed cheeses of such age and moisture content as to be "spready," (3) processed cheese with concentrated whey or skim milk powder added and of such fat and moisture content that the mixture will spread easily. This article concerns itself with cheese spreads of the latter type.

Cheese spreads of this type may easily be distinguished from those of the second type by the presence of the sugar. In a moisture determination, especially if higher temperatures are used, as is commonly the practice with cheese, the sugar caramelizes, giving the mass a dark brown or black appearance. Moisture determinations on such products can therefore be made only with the use of low temperatures and preferably under vacuum.

As far as the authors know there are at this time no legal standards to govern the fat and moisture content of such cheese spread. Table 1 gives the composition of five typical commercial products of this type and of

TABLE 1
Analyses of cheese spreads

SAMPLE NO.	MOISTURE	FAT	FAT IN SOLIDS	SUGAR (LACTOSE)
	per cent	*per cent*	*per cent*	*per cent*
1	41.13	30.66	52.08	2.13
2	43.38	25.48	45.00	5.39
3	44.19	25.63	45.92	6.75
4	44.89	25.16	45.65	4.28
5	44.05	33.27	59.46	4.20*
6	39.62	28.28	46.83	6.25**
7	41.40	30.51	52.06	6.25**
8	38.29	31.57	51.16	6.25**
9	40.74	32.17	54.29	6.25**
10	40.45	33.78	56.72	6.25**
11	39.67	33.87	56.14	6.25**
12	37.80	33.65	54.10	9.50**

* Calculated from figures given by the manufacturer.
** Estimated from the amount of whey powder used.

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[1] Published with the permission of the Director of the Wisconsin Experiment Station.

seven experimental samples. These products are made by methods entirely similar to those used in the manufacture of processed cheese. The ground cheese plus such products as condensed whey, whey powder, or skim milk powder, is processed with the addition of sodium citrate, di-sodium phosphate or Rochelle Salt; water is added according to the mixture used and the consistency desired in the finished product. The desired consistency can also be obtained by using cream instead of water thereby utilizing both the increased fat and moisture content to produce the spreading quality. Usually a small amount of common salt (0.5 per cent or less) is added.

It will be noted that the mixture used in making these spreads, and the composition arrived at, depart appreciably from cheese. As a result they cannot be sold as cheese; actually they are sold as food products under proprietary trade names. Recently the authors made a study of the composition of cheese spreads to determine whether they could be made to conform more closely to the composition of cheese (with respect to fat and moisture content) without sacrificing the desired spreading quality. In harmony with this, the aim was to make spreads with a moisture content of about 40 per cent and with varying fat contents to determine the effect of the fat on the spreading quality. For this purpose mixtures of cheese (old, well-cured), whey powder and cream were processed. The amount of whey solids that may be used is limited by the solubility of the lactose as well as by flavor considerations. In the experimental work the amount of whey powder used was 10 per cent of the mixture. The solubility of lactose at 15°C. (59°F.) is 16.9 parts per 100 parts of water. On the basis of a 40 per cent moisture in the cheese spread, a lactose content of 6.76 per cent would constitute a saturated solution. Since the whey powder contains approximately 65 per cent lactose, 10 pounds of whey powder per 100 pounds of mixture would contribute 6.5 pounds of lactose. That this amount cannot be exceeded to any great extent is indicated by the last sample in table 1 where 15 per cent of whey powder was used and in which very extensive lactose crystallization occurred. The crystals shown in figure 1 were isolated from this sample.

The mixtures that were made consisted of 10 parts of whey powder and 87.5 parts of cheese, cream, and water, 2.0 parts of sodium citrate and 0.5 part common salt. The proportions of cheese, cream and water were varied to produce the desired fat content with a moisture of 40 per cent.

The calculations necessary to arrive at the required mixtures to attain a specified composition must be based upon the fat and moisture content of the cheese, the fat, solids-not-fat and moisture content of the cream and the moisture content of the whey powder. On account of the fact that some of these values were estimated and because of unavoidable evaporation losses in processing, the desired composition was not accurately obtained in all cases. Typical calculations are appended to this article because they are of interest and may find practical application.

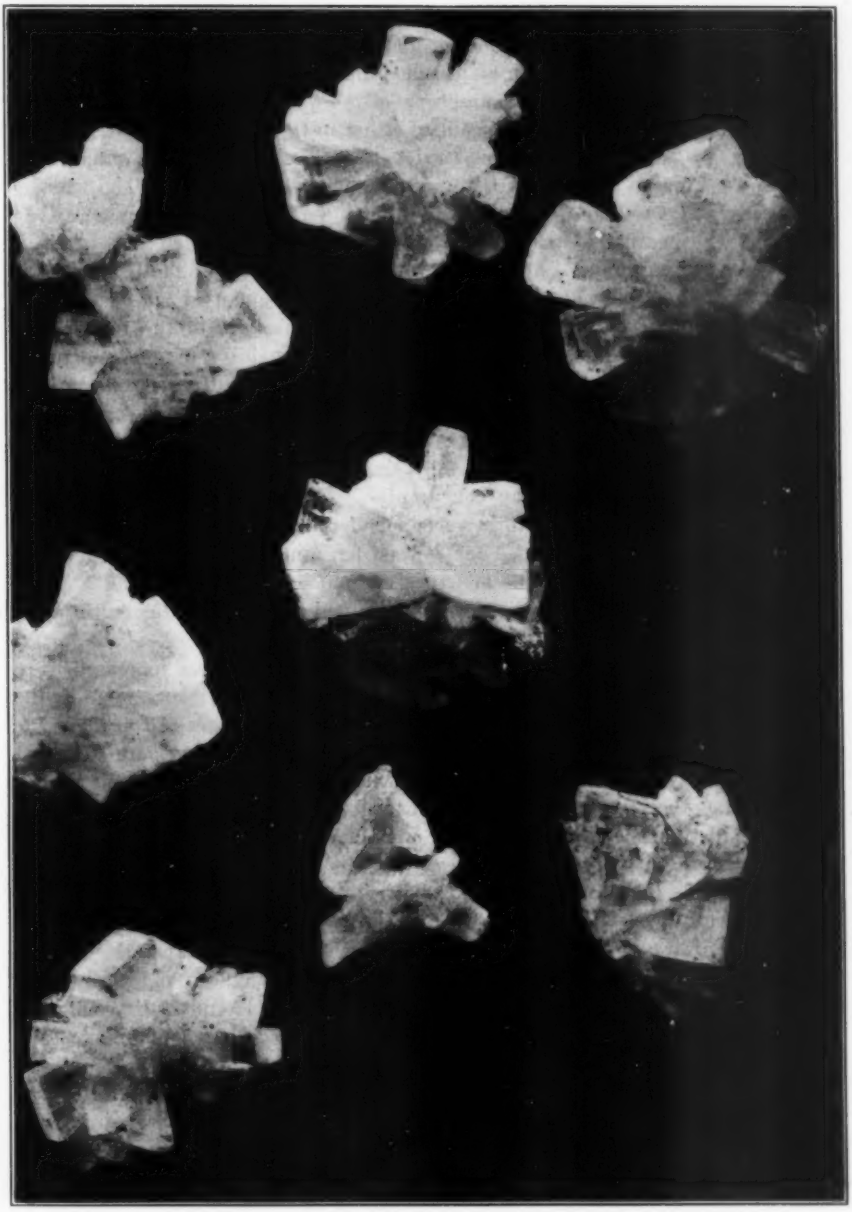

FIG. 1. LACTOSE CRYSTALS ISOLATED FROM A CHEESE SPREAD. MAGNIFICATION 8×

Having calculated the amounts of the constituents to be used, the next step in the process was the blending and heating. These operations were performed at the same time in an ordinary processed cheese kettle. Part of the cheese was put in the kettle and some of the water or cream added. The emulsifying agent to be used was added either in the solid form or dissolved in the water, when the solid was used there was no difficulty as sufficient water was present to dissolve the crystals almost immediately. The whey powder was then added slowly, and the remainder of the cheese, cream and water. The heating of the mixture was started any time after the whey powder had been added. Due to the rather moist nature of the product it was heated to a somewhat higher temperature than that used for processed cheese. Another reason for the higher temperature lies in the fact that the addition of pasteurized cream decreased the acidity of the mixture (increased the pH value) and increased the number of heat resistant, putrefactive organisms present, in addition to those in the cheese, and unless these organisms were killed at this time they would grow under the less acid conditions producing changes that would render the cheese very offensive and unfit for human consumption. For these reasons temperatures of 160° to 180°F. are to be recommended. If the lower temperature is used it should be maintained for at least ten minutes, water being added from time to time to keep the moisture content at the desired level. The amount of water to be added can be determined only by practice with the kettle used.

The effectiveness of the higher temperature treatment was increased by the method in which the spread was packaged. The hot mixture was filled directly into the tin foil lined wooden boxes and the top layer of foil turned over the cheese as soon as possible in order that it would cling more closely to the cheese. The boxes were made of $\frac{3}{8}$ inch lumber and retained the heat very well as they were still warm the next morning. That this slow cooling plays a distinct part in commercial work has been shown in numerous instances by the spoilage of the outside rows of containers in a large stack of boxes while those in the center, that were kept warm for a longer time, kept perfectly.

The sanitary measures used in handling the hot cheese were the same as those employed in the handling of any food product. If old cheese is used or if for other reasons the texture of the product tends to be coarse, it is possible to produce a smooth texture by running the hot cheese mass through a mustard mill, paint mill, or homogenizer. If this method is used, the additional step in the process may be a very fertile source of contamination. Care should be exercised to keep the equipment in a sanitary condition and it is advisable to reheat to at least 160°F. in case the temperature has been allowed to drop.

From the studies that have been made in this laboratory on experimental cheese spreads, samples that have been sent in for inspection and those purchased for study from local retail merchants, there are a number of rather definite conclusions that may be drawn. The spreading quality is due primarily to the fat and moisture content of the sample. In some samples having a rather excessive amount of moisture this factor seemed to be primarily responsible for the spreading quality, but in most cases a somewhat lower moisture content with a higher fat content gave a very satisfactory product. In samples having less than 40 per cent moisture with a corresponding increase in the amount of fat present the product seemed to spread as well as those in which the amount of water exceeded 40 per cent. When the spreading quality was due primarily to the high moisture content, the texture of the sample may be best described as mealy, but as the fat content increased this mealiness disappeared and the texture became more like that of butter. This was shown very clearly in samples 6 to 11 inclusive in table 1. Numbers 10 and 11, having an especially high fat content, were very soft and resembled soft butter. The others were much better in that they did not flatten out as rapidly when removed from the containers. All of these samples spread very easily and smoothly; number 6 showed a slight tendency to be mealy but this was not objectionable. When fresh, sample number 12 had a very desirable spreading quality and this was still evident even after the formation of lactose crystals made it impossible to spread the product in a smooth, buttery manner.

The reaction of cheese spreads varies between rather wide limits depending upon the composition. If there was little or no cream added, the reaction was about the same as for processed cheese, but, if considerable cream had been added, the reaction becomes more nearly alkaline. As has been shown in processed cheese[2] the reaction is important in connection with the keeping quality of the cheese, a cheese with a reaction above pH 6.3 was more apt to spoil than one having a reaction of 6.2 or less, preferably about pH 5.8 to 6.1. This was demonstrated very clearly in the trouble involved in keeping samples of a cheese spread from spoiling. Examination of the fresh samples revealed a reaction of pH 6.2 to 6.4 with a majority nearer the latter figure. Addition of citric acid sufficient to reduce the reaction to pH 5.9 to 6.05 had no noticeable effect on the flavor and the change in reaction was enough to double or triple the length of time that the cheese spread could be kept in an incubator without spoiling. The reaction figures given are for Cheddar or American Cheese and should not be taken as indicative of the reaction to be found in other varieties. A limited amount of work done on Roquefort and Limburger indicated that these cheese spreads had a reaction between pH 6.4 and 6.7. However, no

[2] Templeton, Hugh L., and Sommer, H. H. JOURNAL OF DAIRY SCIENCE, 13: 303. May, 1930.

difficulties were experienced with their keeping qualities. This is probably due to the characteristic fermentations involved in the ripening of these cheeses and the types of organisms that predominate in them.

CALCULATIONS

Before making any calculations of the amounts of cheese and cream to be used in making a cheese spread it is necessary to decide upon the weight of condensed whey, whey powder or skim milk powder that is to be used, the amount of emulsifying salt, and also the weight of common salt that will be added. The percentage of moisture in each of these substances should be known. With the amounts of these ingredients fixed the general equations for the amounts of cheese and cream to be used, may be stated as:

$aX + bY =$ weight of fat desired
$cX + dY =$ weight of solids-not-fat to be obtained from the cream and cheese

In the above equation X is the weight of cheese having (a) per cent of fat and (c) per cent of solids-not-fat, and Y is the weight of cream with (b) per cent of fat and (d) per cent of solids-not-fat. After the desired fat and solids have been obtained, water may be added to make up the remaining weight and supply any needed moisture for the finished product. Two examples will be given to illustrate the use of these equations.

We desire to make a cheese spread having 26 per cent of fat and 42 per cent moisture. There is available whey powder with 3 per cent moisture, sodium citrate (U.S.P. VIII) containing 27.75 per cent water of crystallization, cheese with 32 per cent fat and 37 per cent moisture, and cream testing 40.0 per cent fat and 5.28 per cent solids-not-fat (calc. from 8.8 per cent solids-not-fat in the whole milk). In the cheese spread we want to use 10.0 per cent of whey powder, 2.0 per cent sodium citrate, and 0.5 per cent common salt. The first step is to make a skeleton table and insert such values as are available:

	FAT LBS.	SOLIDS-NOT-FAT. LBS.	WATER LBS.
10.0 lbs. whey powder	0.00	9.70	0.30
2.0 lbs. sodium citrate	0.00	1.45	0.55
0.5 lbs. salt	0.00	0.50	0.00
lbs. cheese			
lbs. cream			
lbs. water			
100.0 Total	26.00	32.00	42.00

From the above table it is evident that the cheese and cream must furnish the 26.00 pounds of fat and 20.33 pounds of solids-not-fat (32.00 – 9.70 – 1.45 – .50). Substituting the known values in the general equations:

$$.32X + .40Y = 26.00$$
$$.31X + .0528Y = 20.35$$

Multiplying by 100 to remove all but one of the decimals:

$$32X + 40Y = 2600$$
$$31X + 5.28Y = 2035$$

By cross multiplication and subtraction it is possible to eliminate one of the unknowns and solve for the other. By this process Y was found to be 14.5 (calculated to the nearest tenth), and when this value was substituted in the first equation, X was found to be 63.1. Therefore, we must use 63.1 pounds of cheese which will supply 20.19 pounds of fat, 19.56 pounds of S. N. F. and 23.35 pounds of water; 14.5 pounds of cream will furnish 5.80 pounds of fat, 0.77 pounds of S. N. F. and 7.93 pounds of water. Summing up we have a total weight of 90.1 pounds containing 25.99 pounds fat, 31.98 pounds S. N. F., and 32.13 pounds of water. The addition of 9.9 pounds of water will give the total weight of 100 pounds making the moisture content 42.03 which is very close to that originally desired. In practice it is wise to add an excess of water to make up for any losses due to evaporation during the heating process.

As a second example let us take a case where the fat content of the cheese spread will be higher and the moisture lower. Because the latter fact the amount of whey powder to be used will have to be reduced to 9.0 pounds in order to be sure that there will be no crystallization of the lactose. The fat content desired will be 32.00 per cent with 38.0 per cent moisture. The ingredients will be the same except the cheese contains 33.0 per cent fat and 35.8 per cent water, while the cream tests 42.5 per cent fat with 5.1 per cent solids-not-fat. Tabulating the figures available:

	FAT LBS.	S. N. F. LBS.	WATER LBS.
9.0 lbs. whey powder	0.00	8.73	0.27
2.0 lbs. sodium citrate	0.00	1.45	0.55
0.5 lbs. salt	0.00	0.50	0.00
lbs. cheese			
lbs. cream			
lbs. water			
100.0 lbs.	32.00	30.00	38.00

In this case the cheese and cream must furnish 32.0 pounds of fat and 19.32 pounds of solids-not-fat. Making the necessary substitutions we get the equations:

$$.33X + .425Y = 32.00$$
$$.315X + .051Y = 19.35$$

Proceeding as before and eliminating the X we find that Y equals 31.7 or the number of pounds of cream while X is found to be 56.2 or the number of pounds of cheese. This weight of cream will supply 13.46 pounds of fat, 1.62 pounds of S. N. F. and 16.62 pounds of water; the cheese furnishes 18.54 pounds of fat, 17.70 pounds of S. N. F. and 19.96 pounds of water. Summing up we have a total of 99.4 pounds containing 32.00 pounds of fat, 30.00 pounds of S. N. F. and 37.40 pounds of moisture. The addition of 0.6 pounds of water is therefore all that is necessary to give the desired composition.

SUMMARY

1. The desirable spreading qualities of cheese spreads may be due to the moisture content or the fat content of the product or a combination of these factors.

2. High moisture with relatively low fat content gives a mealy texture; as the fat is increased, the consistency becomes like that of butter.

3. High fat and high moisture results in a weak bodied spread that does not give a very pleasing appearance when removed from the container.

4. In making cheese spreads it is essential to heat to a higher temperature because of the high moisture content, less acid reaction, and the presence of putrefactive organisms (if cream is used).

5. The reaction of the cheese spread affects its keeping quality; reactions of pH 5.8 to 6.1 were found to be very satisfactory.

6. A method for the calculation of the amounts of the different ingredients to be used has been worked out and examples given of its application.

The authors wish to express their thanks to Mr. Harry Klueter and Dr. E. O. Huebner for supplying part of the data used in the table.

THE INFLUENCE OF NON-STRIPPING ON THE BACTERIAL COUNT OF MACHINE-DRAWN MILK[1]

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Two practises have developed which make timely a consideration of the influence of non-stripping of cows on the bacterial count of machine-drawn milk. In the first place the bacterial count of milk is used extensively in milk control work as a measure of the cleanliness and desirability of the product. While the types of bacteria present should receive more consideration perhaps than commonly accorded them, yet it is true that large numbers of bacteria are often associated with carelessness in producing and handling the milk. For this reason, the bacterial count serves a useful purpose in giving some indication of the quality of the milk.

If the bacterial count is to be used as an indication of quality and hence in determining to some extent the price received, it becomes important to consider production practises which may affect the number of bacteria present.

Then, in the second place, another practise is introduced for consideration. The returns from the milk obtained by stripping, following the use of a machine, are small in proportion to the extra time and inconvenience involved in doing the stripping.

While most investigators have expressed the belief that stripping is necessary, the practise has been discontinued on some dairy farms with seemingly no deleterious effects. Dairymen producing Certified and other high quality milk, as evidenced by a low bacterial count, are at once confronted with the question as to whether or not non-stripping will have a tendency to increase the bacterial count of the milk produced. A survey of the literature revealed no investigations bearing directly on the problem. Heineman[2] reported work by Lux in which he found an increasing count in samples of milk drawn at increasing intervals of time varying from two hours to twenty-four hours between milkings. This was interpreted as indicating bacterial multiplication in the udder. Stocking[3] found an in-

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[1] The data upon which this paper is based were taken from a thesis presented by G. C. Wallis in partial fulfillment of the requirements for the degree of M.S., University of Minnesota.

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[2] Heinemann, Paul G. Milk, pp. 267–314. W. B. Saunders Co., Philadelphia. 1919.

[3] Stocking, W. A., Jr. Quality of milk affected by common dairy practises. Conn. (Storr's) Agr. Exp. Sta. Bul. 42: 66–90. 1906.

crease in the bacterial count from an average of 6,542 to 11,324 when strippings were left in the udder at the previous milking under hand milking conditions.

The work reported in this article was planned for the purpose of securing some more definite data concerning any change that might occur in the bacterial counts of milk when stripping was not practised.

EXPERIMENTAL

Two lines of approach were followed in obtaining information on this problem. The milking machine as a factor contributing to the bacterial count of the milk was eliminated in the first plan. Six animals were used in this part of the experiment. The milking machine was stopped after it had obtained approximately one-half of the milk. A sample of the middle milk was then drawn separately from each quarter by hand under aseptic conditions. The samples were taken to the laboratory immediately for plating. Samples were obtained in this way from each animal in a two day preliminary period in which stripping was practised regularly. For the next two days stripping was discontinued and samples taken as before. Following this, stripping was again practised and samples taken for two days in a check period. The teats were sealed with collodion between milkings in all of these trials.

The samples were plated in duplicate in at least two, and usually three dilutions. Beef infusion agar was used. The plates were incubated for two days at 37° C. and all plates counted. The most representative dilution was then selected and used as the count of that sample. Representative results obtained from two of the animals used in this work are presented in table 1.

It was conceivable that the foremilk might contain large numbers of bacteria when the strippings were not removed at the previous milking. If the contamination of the foremilk was heavy the bacterial count of the whole milking might be increased by a measurable amount. This condition would not be detected by sampling the middle milk as outlined above. Consequently, the second approach to the problem was designed to cover this point. Two cows were used for this trial. The entire milking was drawn into a specially sterilized milking machine and a sample obtained from this to be used in plating. During the progress of the investigation a check was made to ascertain the bacteriological condition of the milking machine. It was found that the method of cleaning and sterilizing employed was maintaining it in a satisfactory condition.

During the first six day trial with each animal the teats were sealed with collodion between milkings to prevent a variable contamination from this source. The six day trial consisted of two days in which the cows were stripped, followed by two in which stripping was not practised, then two

TABLE 1

The effect of non-stripping on the bacterial count of aseptically drawn milk as measured by sampling the middle milk

DATE	BACTERIAL COUNTS			
	Right fore quarter	Left fore quarter	Left hind quarter	Right hind quarter
	per cc.	*per cc.*	*per cc.*	*per cc.*
		Cow 155		
Stripped previously				
12–26–30 p.m.	220	25	75	40
12–27–30 a.m.	70	20	75	35
p.m.	500	30	25	25
12–28–30 a.m.	1845	30	50	10
p.m.	116	197	24	7
Not stripped previously				
12–29–30 a.m.	365	16	50	27
p.m.	615	6	60	20
12–30–30 a.m.	125	21	17	6
p.m.	173	15	11	7
Stripped previously				
12–31–30 a.m.	380	6	9	7
p.m.	20	10	17	9
1– 1–31 a.m.	121	7	27	12
p.m.	1085	11	148	9
		Cow 396		
Stripped previously				
1– 2–31 a.m.	19,000	100	10	16
p.m.	6,250	18	15	19
1– 3–31 a.m.	9,150	6	7	12
p.m.	3,150	2	13	11
Not stripped previously				
1– 4–31 a.m.	12,300	10	24	48
p.m.	3,300	10	19	16
1– 5–31 a.m.	4,700	8	18	21
p.m.	6,100	21	12	13
Stripped previously				
1– 6–31 a.m.	3,850	12	27	20
p.m.	5,900	141	79	277
1– 7–31 a.m.	6,850	295	198	185
p.m.	4,900	222	26	33

days of stripping again, similar to the plan in the first experiment. Each animal was then used in an eight day trial consisting of alternating two-day periods of stripping and non-stripping in which the teats were not sealed between milkings. In both parts of the work the udders were carefully washed with a hypochlorite solution and dried before starting the milking. Other necessary precautions were taken to obtain the sample of milk aseptically. The same bacteriological methods were employed as previously explained. The results obtained in these trials are given in table 2.

Discussion

The data were carefully analyzed by a study of the trend of the counts obtained from period to period for each animal by quarters. The data for all the animals have not been included but it may be noted in the repre-

TABLE 2

The effect of non-stripping on the bacterial count of aseptically drawn milk as measured by a sample of the whole milking

cow 542			cow 382		
Date		Bacterial count whole milking	Date		Bacterial count whole milking
		per cc.			*per cc.*
		Teats sealed			
Stripped previously					
2–11–31	a.m.	10,450	3–17–31	a.m.	105
	p.m.	5,050		p.m.	55
2–12–31	a.m.	48,000	3–18–31	a.m.	160
	p.m.	107,500		p.m.	40
Not stripped previously					
2–13–31	a.m.	167,500	3–19–31	a.m.	125
	p.m.	181,000		p.m.	105
2–14–31	a.m.	101,000	3–20–31	a.m.	45
	p.m.	21,350		p.m.	25
Stripped previously					
2–15–31	a.m.	9,200	3–21–31	a.m.	170
	p.m.	5,550		p.m.	360
2–16–31	a.m.	4,900	3–22–31	a.m.	490
	p.m.	5,150		p.m.	305
		Teats open			
Stripped previously					
2–17–31	a.m.	3,700	3–23–31	a.m.	1745
	p.m.	2,690		p.m.	850
2–18–31	a.m.	2,470	3–24–31	a.m.	515
	p.m.	7,750		p.m.	435
Not stripped previously					
2–19–31	a.m.	15,100	3–25–31	a.m.	935
	p.m.	28,300		p.m.	755
2–20–31	a.m.	64,000	3–26–31	a.m.	920
	p.m.	76,000		p.m.	3810
Stripped previously					
2–21–31	a.m.	35,500	3–27–31	a.m.	1660
	p.m.	11,850		p.m.	1040
2–22–31	a.m.	21,750	3–28–31	a.m.	450
	p.m.	27,250		p.m.	670
Not stripped previously					
2–23–31	a.m.	7,950	3–29–31	a.m.	8260
	p.m.	18,500		p.m.	725
2–24–31	a.m.	44,000	3–30–31	a.m.	915
	p.m.	78,500		p.m.	1870

sentative results shown in table 1 that the two highest counts for the right fore quarter of cow 155 occurred during the stripping periods. There is no abnormal fluctuation during the non-stripping period for any of the quarters. Referring to the last part of table 1, we have no indication that non-stripping tended to increase the counts obtained from cow 396. In fact, the counts are somewhat higher in the last two-day period when stripping was practised regularly. With cow 542 (data not published) the right fore quarter and the left hind quarter had considerably higher counts than the other two. A slight indication of garget was noted in the right fore quarter but the onset was during the preliminary period when

stripping was practised, and by the end of the non-stripping period the disturbance had subsided, so the cause can not be attributed to the non-stripping procedure. In the remaining two quarters the counts were somewhat lower during the non-stripping period. A careful study of the data from all six of the cows reveals nothing but normal fluctuations and gives no indication of an increase in the bacterial counts during the non-stripping periods as measured by aseptically drawn samples of the middle milk.

Referring to table 2 giving the data obtained when samples of the whole milking were used, we find practically the same situation. When the teats were sealed on cow 542, the counts were ascending somewhat during the preliminary stripping period. The peak was reached at the second milking during the non-stripping period and by the end of this period the count was relatively low again. In the trials with the teats unsealed the fluctuations from period to period show no decided changes, a count somewhat higher than the rest appearing in each of the non-stripping periods, however.

The results with cow 382 also given in table 2 show some of the lowest counts in the trials with the teats sealed to be in the non-stripping period with a tendency toward higher counts during the last period when stripping was practised. In the first non-stripping period when the teats were left open, the first three counts are on approximately the same level while the last count is somewhat higher. The condition is similar in the second non-stripping period except it is the first count that is a little higher. By studying the data carefully in this manner no conclusive evidence is found to indicate an increase in the bacterial count when the strippings are not removed.

Distribution curves were made as a further step in analyzing the data obtained. A frequency distribution was made of all the bacterial counts obtained during the stripping periods in the first part of the experiment where the middle milk was sampled. These were converted into percentages for each class interval for purposes of comparison. All bacterial counts obtained in the non-stripping periods of all six animals were treated in the same way. The data obtained were plotted as shown in figure 1. The solid line represents the distribution of bacterial counts obtained in the stripping periods and the broken line, those of the non-stripping periods. A study of the graph indicates that there was a somewhat higher percentage of the lower counts during the non-stripping periods. Likewise, the percentage of higher counts is less during the non-stripping periods. According to this analysis the results are somewhat more favorable to the non-stripping periods.

A graph was made in a similar way to represent the data obtained in the stripping and non-stripping periods in the second part of the experiment when the whole milking was sampled. Figure 2 shows the results obtained. The solid line again represents the stripping periods and the

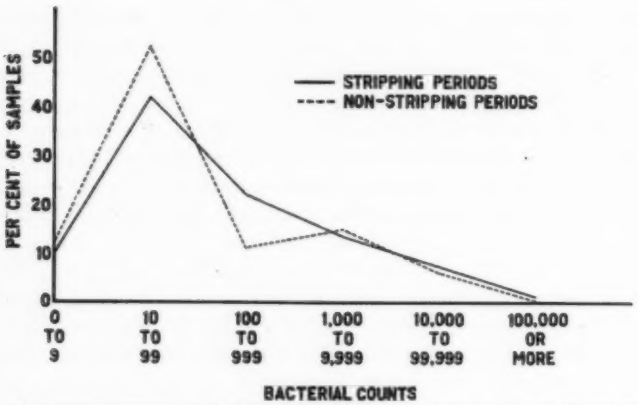

FIG. 1. THE DISTRIBUTION OF BACTERIAL COUNTS AS OBTAINED FROM SAMPLES OF THE MIDDLE MILK DURING STRIPPING AND NON-STRIPPING PERIODS.
(DATA BASED ON 296 SAMPLES)

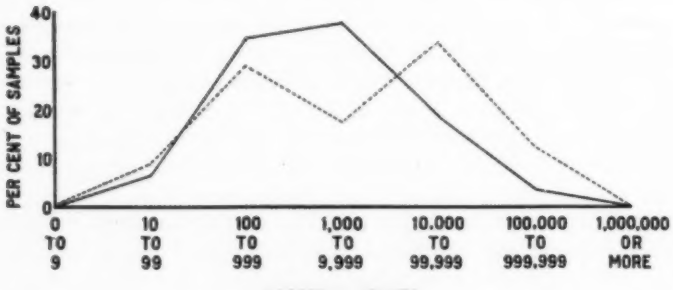

FIG. 2. THE DISTRIBUTION OF BACTERIAL COUNTS AS OBTAINED FROM SAMPLES OF THE WHOLE MILKING DURING STRIPPING AND NON-STRIPPING PERIODS.
(DATA BASED ON 56 SAMPLES)

broken line, the non-stripping periods. The percentage of lower counts favors the non-stripping periods only slightly in this case. The two lines then follow each fairly closely until the higher counts are reached when the broken line shows some irregularity and indicates a tendency for a slightly higher percentage of the higher counts in the non-stripping periods. Considering all the factors, the results as indicated in this graph are slightly in favor of the stripping periods. While the amount of data in this second method of investigation is not as large as might be desired, from which to draw a specific generalization, still, sufficient work has been done to indicate what might be expected when stripping is discontinued. A careful study of the data obtained shows no positive evidence that leaving strippings in

the udder will increase the bacterial counts of subsequent milkings, as measured in alternating two day trials. If further work should follow the tendency indicated in figure 2 rather than show normal fluctuations similar in the stripping and non-stripping periods, the present indications are that the increase in bacterial counts from non-stripping would, at least, be slight. The results when sampling the middle milk are slightly in favor of the non-stripping period as shown in figure 1, while the results when sampling the whole milking are slightly in favor of the stripping period, as shown in figure 2, so that the variations noted in the data presented would seem to be more logically explained as normal fluctuations.

A few other interesting observations may be made from the data obtained in this investigation. In agreement with many previous investigations, the bacterial counts of the different quarters of the udder are independent of each other. Some quarters may have high counts while others of the same animal run consistently much lower, as with right fore quarter of 396, and 155 noted in table 1. Similar conditions were noted in the unpublished data for 542 and 402. The counts may be increasing in some quarters while decreasing in others.

Likewise, there is no evidence of a correlation between the thoroughness of machine milking and the normal bacterial count of the cow. Cow number 542 milked out poorly and showed a high count, while 547 also retained considerable strippings but had a low count. On the other hand cow 155 milked out well and had a low count, while 409 milked out equally well but gave a much higher count.

It might also be expected that cows milking out poorly with the machine would have a greater tendency toward increased bacterial counts in non-stripping periods, but this was not found to be the case in the present investigation. The results were negative with both types of animals.

The effect of retained strippings on the bacterial content of milk from high count cows can be compared with normally low count animals. Again, no difference appeared. As measured by a sample of the middle milk there was no increase in the bacterial count during the non-stripping period with either the high or low count type.

Some idea may also be gained as to the effect of sealing the teats on the resulting bacterial count. According to information in table 2, for cow 542, the counts run somewhat higher where the teats were sealed, and the lowest counts of the entire series are in the first part of the period when the teats were left open. With cow 382, the opposite is the case. The lowest counts were obtained when the teats were sealed. The fluctuations are approximately as violent in one case as the other so no definite claims can be made for or against the sealing of the teats.

CONCLUSIONS

From a study of the data presented the following conclusions seem justified.

1. There is no positive evidence that leaving strippings in the udder will increase the bacterial count of the subsequent milkings, as measured in alternating two-day periods of stripping and non-stripping. The variations noted would seem to be more properly explained as normal fluctuations.

2. The bacterial counts of the different quarters of the same udder are independent of each other.

3. There is no correlation between the thoroughness of the machine milking and the normal bacterial count of aseptically drawn milk.

4. The effect of non-stripping on the bacterial count of the milk is negative with cows that milk out poorly, as well as with those that milk out well with the machine. The same is also true for cows normally of the high count type and those of the low count type.

5. Sealing the teats with collodion between milkings seemed to have no noticeable effect in reducing the bacterial counts or preventing the relatively wide fluctuations.

THE BEHAVIOR OF COWS ON ALFALFA HAY AS THE SOLE ROUGHAGE AND ON ALFALFA AND TIMOTHY COMBINED

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INTRODUCTION

For the past ten years the Beltsville Station of the Bureau of Dairy Industry has been carrying out work directed toward discovering methods of feeding and treatment for dairy cows which could be easily controlled experimentally and which would keep cows for an indefinitely long period in good health and at optimum or nearly optimum milk-producing and reproductive capacity. This problem is by no means solved, but certain cows have done moderately well on fairly uniform rations for periods of about five years, and some important landmarks in the field of experimentation seem to be outlining themselves. It is worth-while, therefore, to give a partial account of the results, emphasizing particularly certain aspects of them which bear on the question of the importance of hay in the dairy ration.

OUTLINE OF METHODS OF FEEDING AND TREATMENT

The cows are, of course, kept entirely off pasture. The rations fed consisted at first of grain combined with either alfalfa or timothy hay and corn silage. In the year 1922, however, an epidemic of scouring and digestive disturbance broke out in the experimental herd, which, it was thought, might be due to some unusual molds or bacteria in the corn silage. From that time on a number of cows were fed on grain with either alfalfa or timothy hay as the sole roughage, although certain others continued to receive one of the two kinds of hay and silage in addition.

When the cows were dry, it was aimed to feed them ten per cent more total digestible nutrients than they required according to the Savage standard (6, p. 133). After they calved, it was often found that for some time they would not eat as much as they required according to this standard. It was aimed, however, to feed as much as they required for the first two clear calendar months after calving. When this could not be accomplished, they were fed as much as they would eat. After they had been milking for two clear calendar months, it was aimed to feed them ten per cent more than they required according to the Savage standard, and to continue this surplus feeding until the next calf was born. As a matter of fact, however, the cows were not infrequently fed somewhat more than the above schedule

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calls for. The rations used were high in protein, so that when the cows ate ten per cent more total digestible nutrients than they required according to the Savage standard they usually consumed from thirty to seventy per cent more digestible protein than they required.

The cows which received silage were fed 9 kilograms of it or less daily, as much hay as they would eat, and enough grain to bring their consumption of total digestible nutrients up to the schedule which has just been given. In the case of those fed only grain and hay, it has been the aim to feed equal quantities by weight of grain and hay. When, however, it was found that the cows would not eat enough on this basis to supply what they required to conform to the schedule of feeding, they were given as much hay as they would eat, and enough grain to conform to the schedule. The grain mixtures used for the cows for which data are given in this paper were numbers 40, 50, 60, and 75. Their composition is given in table 1.

TABLE 1

*Composition of grain mixtures**

Grain 40		*Grain 60*	
Corn meal	50	Corn meal	40
Wheat bran	50	Wheat bran	30
Salt	1	Soybean meal	20
		Linseed meal	10
		Salt	1
Grain 50		*Grain 75*	
Corn meal	40	Corn meal	40
Wheat bran	30	Wheat bran	40
Cottonseed meal	20	Linseed meal	20
Linseed meal	10	Salt	1
Salt	1		

* The corn meal used throughout the experiments was yellow. The cottonseed, linseed, and soybean meals had their fat extracted by the old process, that is, without fat solvents.

In the earlier stages of the experiments, from 1920 until 1924, the quality of the hay used was not carefully controlled and a number of the experimental animals got either alfalfa or timothy hay which was of mediocre and sometimes probably of rather poor quality. After 1924, however, and in all of the experiments for which figures are given in this paper, it was aimed to feed only hay of high quality. The alfalfa hay used was mostly of U. S. No. 1 grade (8). For short periods, sometimes, it was found necessary to feed hay of a high No. 2 grade, but these periods were balanced by others in which extra leafy and extra green alfalfa was fed, so that all the alfalfa fed may be regarded as of No. 1 grade on the average. In the case of timothy hay, it is sometimes practically impossible to get the U. S. No. 1 grade (8). At such times a high grade No. 2 hay was fed, but most of the timothy fed was of the No. 1 grade, and all of it, of good quality.

When indoors the cows are kept in stanchions. They are turned out in a lot where there is no grass for at least two half-hour periods every day to get water. Through most of the summer, and in good weather in winter, they spend a considerable portion of the day in this lot.

The cows are fed individually in smooth cement mangers, so that any food left by them can be conveniently removed and weighed. All the daily portions of grain, hay and silage offered to them are weighed and if, after a certain interval, these are not consumed the portions left are removed and weighed. Daily records of all the feed consumed have been kept as well as of all the milk yielded. In the early stages of the experiments the fat content of the milk from each cow was determined by the Babcock test on two days each month. More recently this test has been made three times a month, each time on two successive days.

For convenience many of the records have been kept on the basis of calendar months. At the end of each calendar month the daily milk yields of each cow are added up and the sum for the month is recorded. The fat yield for the month is calculated from this sum by means of the average test as determined from the Babcock tests. The weights of all feeds consumed are also added up at the end of the month and the sums recorded.

Each cow is weighed on three successive days at the beginning of each month, and the average weight for the three day period is recorded.

From the body weights of the cows and the monthly milk and fat yields, their requirements for digestible protein and total digestible nutrients according to the Savage standard are calculated. Their consumption of digestible protein and total digestible nutrients for the month is also calculated from the consumption of the various feeds, using the average figures for the digestible protein and total digestible nutrients of dairy feeds which are given by Henry and Morrison (6, p. 653). The requirement and consumption are recorded and compared, and used as a guide in feeding the cows from month to month according to the foregoing schedule.

The heifers are bred for the first time at the age of twenty-one months. After they calve, the animals are not bred until they have been milking for six clear calendar months. If the calving date falls less than seven days before the beginning of the succeeding calendar month, the next month after this is generally counted as the first clear calendar month of lactation. The cows are dried off after they have been milking for twelve clear calendar months or more, it being the aim to make the dry period about one-quarter the length of the milking period. If they become pregnant as the result of the first breeding, the milking period is only a little over twelve months; if there is delay about getting them with calf, it may be considerably longer.

EXPERIMENTAL RESULTS

It was observed fairly early in the experiments that the cows which got timothy hay of mediocre quality, whether or not combined with corn silage, would not eat large quantities of it, and that after a time they showed a strong desire to steal alfalfa from their neighbors. Sometimes they ate only very small quantities of hay and would then show a general loss of appetite, reduction in milk yield, and signs of general sickness. They sometimes recovered from this condition when alfalfa was substituted for the timothy hay.

Five cows which were fed for long periods on timothy of mediocre quality, either as the sole roughage or combined with corn silage, lasted on the average only a little more than a year and a half, and in no case for as much as three years. They either died of illnesses, which were variously diagnosed, or failed to become pregnant, though bred repeatedly.

Five cows, on the other hand, have now been on alfalfa hay either as the sole roughage or combined with other roughages for periods of over five years. These are cows 71, 84, 458, 470, and 482. Cows 71 and 84 are grade Guernseys; cows 458, 470, and 482, pure-bred Jerseys. It is the history of these five cows which forms the particular subject of this article.

One of these, cow 84, has been on grain, alfalfa, and silage since November 1, 1924, and is still doing fairly well at present (March 4, 1931) at the age of over thirteen years.[1] A second one, cow 458, has been on grain with alfalfa as the sole roughage since November 1, 1926,[2] and is still doing well at present at the age of over nine years.[3] The other three, namely, cows 71, 470, and 482, were fed on grain with alfalfa as the sole roughage for periods of from two years and nine months to three years and three months. It was noticed that these cows as well as others which were kept for long periods on alfalfa as the sole roughage, or on alfalfa combined with corn silage, showed a strong desire to steal timothy hay from their neighbors. This suggested that a ration in which alfalfa was the sole hay fed might not be altogether ideal for dairy cows, and led to the experiments on feeding alfalfa and timothy together which form the subject of this article.

One of the three cows mentioned above, No. 482, did not eat hay well during her lactation period of 1926–27, and left small quantities even during the subsequent dry period. She aborted September 24, 1927, after a dry period of about four months, but six weeks before the calf was due. She did not show any very marked loss of appetite at this time, but in view of the observations mentioned above it was suggested by one of us (H. T. C.) that she be given some timothy hay along with the alfalfa. The suggestion was acceded to with some reluctance by the other author, as it seemed doubt-

[1] Born Oct. 11, 1917.

[2] She was on grain with alfalfa and silage for some time before this.

[3] Born June 20, 1921.

ful whether it was wise to break the continuity of an experiment on feeding grain and alfalfa which had already continued for nearly three years. However, the cow was offered 1.8 kilograms of timothy hay daily beginning the fourth day after calving and continuing for some weeks thereafter. Some of the details of her behavior for the first six weeks after calving are given in table 2. In spite of the combined timothy and alfalfa feeding, she was badly off feed in the first and second weeks after calving. She showed a decided preference for timothy over alfalfa, however, not only for the six weeks after calving, for which data are given in table 2, but also for the second, third, and fourth months after calving. After that she returned to a preference for alfalfa hay. Her milk yield, in spite of the abortion, was decidedly higher than it had been in either of her two previous lactations.

Cow 482 had been on grain, timothy, and alfalfa for about a year when cow 470 calved on October 1, 1928. Data regarding her behavior for two weeks before and six weeks after calving are given in table 2. She showed no particular distaste for alfalfa in the lactation period preceding this calving, and her appetite was good in her dry period and up to the time of calving. In the first two weeks after calving, however, she was very badly off feed, eating less than half of the very moderate amounts of hay and grain offered to her. On three days scattered through this period she ate no grain at all, and on two days no alfalfa hay. On the last day of the second week, she was offered 2.5 kilograms of timothy hay which she ate up clean, at the same time refusing completely the 2.5 kilograms of alfalfa which were offered to her. From this time on she was offered gradually increasing quantities of both timothy and alfalfa and ate some of each but showed a decided preference for the timothy. Table 2 shows how her appetite and milk yield improved and how definitely she preferred timothy to alfalfa during the third, fourth, fifth, and sixth weeks after calving, when she was fed grain combined with the two kinds of hay. Her preference for timothy lasted all through the subsequent lactation period, though she ate large quantities of both kinds of hay.

Cow 71 calved on December 1, 1928. Some details of her behavior are shown in table 2. She showed some distaste for alfalfa hay for a week before and for three or four weeks after calving, and the question of giving her timothy in addition to alfalfa was considered. Decision was delayed on account of the absence of one of the authors from the experiment station, but she was given three kilograms of timothy on the last day of the eighth week after calving. By this time she was eating satisfactory quantities of alfalfa hay but was still refusing considerable portions of the grain which she required according to the Savage Standard for her maintenance and milk yield. In the ninth week after calving and subsequently she was offered gradually increasing quantities of both alfalfa and timothy hay.

TABLE 2

Food consumption and milk yield of cows 482, 470, and 71, for periods immediately before and after calving.

PERIOD	DAILY AVERAGE									CONSUMPTION[1] AS PER CENT OF REQUIREMENT[1]
	GRAIN		ALFALFA		TIMOTHY		TOTAL HAY EATEN	MILK YIELD	TOTAL DIGESTIBLE NUTRIENTS REQUIRED	
	Offered	Eaten	Offered	Eaten	Offered	Eaten				
	kgs.	*kgs.*	*kgs.*	*kgs.*	*kgs.*	*kgs.*	*kgs.*	*kgs.*	*kgs.*	
Cow 482[2]										
Week before calving										
Second	3.6	3.6	3.5	3.1	0	0	3.1	.....	4.24	98.6
First	3.6	3.5	3.5	3.2	0	0	3.2	.....	4.29	97.0
Week after calving										
First	5.0	4.0	3.7	2.4	1.0	0.9	3.3	8.7	7.99	56.8
Second	5.6	2.0	3.6	0.5	1.8	0.6	1.1	9.4	8.21	25.1
Third	5.9	5.5	3.6	2.7	1.8	1.8	4.5	10.3	8.59	74.6
Fourth	6.6	4.3	3.6	2.1	1.8	1.7	3.8	12.4	9.52	54.1
Fifth	7.0	7.0	3.6	2.1	1.8	1.8	3.9	13.7	10.09	71.8
Sixth	8.6	8.6	3.6	2.2	2.5	2.5	4.7	15.4	10.75	82.2
Cow 470[3]										
Week before calving										
Second	3.6	3.6	3.5	3.4	0	0	3.4	.....	3.58	124.9
First	3.6	3.6	3.5	3.4	0	0	3.4	.....	3.63	123.1
Week after calving										
First	6.5[4]	3.6	3.8	2.6	0	0	2.6	9.9	8.34	33.8
Second	4.6	1.6	4.6	1.5	0.4	0.4	1.9	9.3	7.99	27.2
Third	4.7	3.1	2.5	1.6	3.2	3.1	4.7	9.6	8.09	57.7
Fourth	5.3	4.9	2.6	2.0	3.0	3.0	5.0	12.9	9.66	64.1

[1] Of total digestible nutrients.
[2] Born 6/3/22; calved 9/24/27.
[3] Born 9/17/21; calved 10/1/28.
[4] On account of unwillingness to eat grain No. 60, cow 470 was offered considerable quantities of bran during this week.

TABLE 2—*Continued*

Food consumption and milk yield of cows 482, 470, and 71, for periods immediately before and after calving.

PERIOD	DAILY AVERAGE									CONSUMPTION[1] AS PER CENT OF REQUIREMENT[1]
	GRAIN		ALFALFA		TIMOTHY		TOTAL HAY EATEN	MILK YIELD	TOTAL DIGESTIBLE NUTRIENTS REQUIRED	
	Offered	Eaten	Offered	Eaten	Offered	Eaten				
	kgs.	*kgs.*	*kgs.*	*kgs.*	*kgs.*	*kgs.*	*kgs.*	*kgs.*	*kgs.*	
Cow 470[3]										
Fifth	5.9	5.9	3.0	2.8	3.1	3.1	5.9	14.5	9.97	74.1
Sixth	6.4	6.4	3.3	3.1	4.1	4.1	7.2	15.4	10.05	83.8
Cow 71[3]										
Week before calving										
Second	4.0	1.9	3.5	3.2	0	0	3.2	.....	4.41	68.7
First	4.0	3.3	3.5	1.8	0	0	1.8	.....	4.43	75.2
Week after calving										
First	5.4	4.9	4.2	3.7	0	0	3.7	10.4	8.23	66.5
Second	7.9	4.5	5.4	4.5	0	0	4.5	13.6	9.47	59.0
Third	8.0	5.0	6.5	5.6	0	0	5.6	14.0	9.58	68.2
Fourth	8.0	4.9	6.6	5.8	0	0	5.8	15.7	10.25	63.9
Fifth	8.0	4.3	7.0	6.9	0	0	6.9	15.8	9.97	67.1
Sixth	8.0	7.2	7.4	6.2	0	0	6.2	17.6	10.40	81.1
Seventh	8.0	6.1	8.0	7.8	0	0	7.8	17.8	10.48	80.6
Eighth	8.0	5.2	7.6	7.5	0.4	0.4	7.9	16.1	9.84	79.7
Ninth	8.0	7.3	5.1	4.9	4.4	4.2	9.1	16.3	9.84	100.4
Tenth	8.0	8.0	5.5	5.5	5.5	4.4	9.9	16.2	9.70	111.2
Eleventh	8.4	7.8	5.5	5.5	5.2	3.9	9.4	16.9	9.96	104.4

[3] Born 7/15/16; calved 12/1/28.

TABLE 3

Yearly amounts of food eaten, and percentage total digestible nutrients consumed above or below requirements by cows on various rations.

DATES OF PERIODS	KIND OF GRAIN	AMOUNT OF GRAIN EATEN	ALFALFA HAY EATEN	TIMOTHY HAY EATEN	CORN SILAGE EATEN	TOTAL DRY ROUGHAGE EATEN	CONSUMPTION[1] AS PER CENT ON REQUIREMENT[1]
Cow 71	*No.*	*kgs.*	*kgs.*	*kgs.*	*kgs.*	*kgs.*	
5/1/26 to 4/30/27	75	2625	2425	0	0	2425	111.1
10/1/27 to 9/30/28	40 & 75[2]	2153	2081	0	0	2081	119.0
1/1/29 to 12/31/29	75	2273	1563	979	0	2542	113.1
Cow 84							
4/1/25 to 3/31/26	50	2054	1921	0	2040	2458[3]	128.9
12/1/26 to 11/30/27	60	2265	1905	0	1560	2315[3]	109.3
4/1/28 to 3/31/29	50	2265	1994	0	1696	2440[3]	107.2
11/1/29 to 10/31/30	50	2214	1997	0	2227	2583[3]	117.0
Cow 458							
4/1/27 to 3/31/28	60	2597	2196	0	0	2196	98.0
7/1/28 to 6/30/29	60	2501	1829	0	0	1829	95.3
Cow 470							
1/1/26 to 12/31/26	75	2891	2483	0	0	2483	107.3
6/1/27 to 5/31/28	60	2797	2293	0	0	2293	105.7
11/1/28 to 10/31/29	60	2648	1324	1567	0	2891	108.0
3/1/30 to 2/28/31	60	3029	1521	1663	0	3184	105.5
Cow 482							
1/1/25 to 12/31/25	50 & 75[4]	1922	1997	0	2104	2550[3]	115.8
5/1/26 to 4/30/27	75	2697	1845	0	0	1845	107.6
10/1/27 to 9/30/28	60	2779	1167	995	0	2162	101.8
2/1/29 to 1/31/30	60	2572	1285	1047	0	2332	104.3

[1] Of total digestible nutrients.
[2] 1101 kg. of No. 40 and 1052 kg. of No. 75.
[3] Weight of alfalfa plus weight of dry matter in the corn silage eaten.
[4] 1767 kg. of No. 50 and 155 kg. of No. 75.

Her appetite improved very markedly and she soon ate more than enough grain and hay combined to cover her requirements. Her milk yield also rose somewhat above what it had been in the eighth week after calving, though it never again reached the rather high level which had been maintained through the sixth and seventh weeks after calving. Unlike cows 470 and 482, however, cow 71 did not show any preference for timothy over alfalfa at any time during the subsequent lactation period. During most of the period she showed a quite definite preference for alfalfa.

Cows 71, 470, and 482 did so well in their first lactation periods on grain with alfalfa and timothy hay combined that they have been continued on these rations, as far as possible, up to the present time. Some details of their performance are given in tables 3 and 4. Similar figures for the performance of cows 84 and 458 are put in for comparison. Cow 458 is a cow of about the same milk-yielding capacity as cow 470, and has been on grain with alfalfa as the sole roughage since November 1, 1926. The figures in tables 3 and 4 represent the food consumption, milk yield, etc., in periods, each of which lasted 365 days.

The first point to which attention should be called is that the cows ate decidedly more hay when they got alfalfa and timothy together than when they got alfalfa alone. In connection with this point the figures in table 3 for hay consumption during whole lactation periods should be supplemented with figures for individual months of lactation. Such figures are given in table 5. The cows usually eat the largest amounts of hay in the early months of lactation, while the milk yield is still large, and it is at this time that the greatest differences appear in their willingness to consume alfalfa as the sole roughage on the one hand and alfalfa and timothy combined on the other. It appears from the figures given in table 5 that cows 71, 470, and 482 consumed about 30 per cent more of the combined hays on the average in their record months than they did of alfalfa alone. Table 5 contains figures for the roughage consumption of cows 84 and 458 as well as of cows 71, 470, and 482. These figures give some further evidence for the view that it is difficult to get cows of the Jersey and Guernsey types to eat as much as 8 kilograms of roughage daily, when the roughage in question consists of alfalfa hay alone. In commenting on the results given in table 5, it may be stated that an effort was always made to get the cows to eat as much roughage as possible.

The figures for milk and fat yield given in table 4 are also interesting. Cow 71 gave much more milk and fat in the first lactation on grain, alfalfa, and timothy than in the previous lactation on alfalfa as the sole roughage. It is true that the milk and fat yields on the combined hays were markedly less than they had been about three years before on alfalfa as the sole roughage, but cow 71 was well over 12 years old when she was first put on the combined hays, and her failure to improve on her best previous record

TABLE 4

Yearly milk and fat yields and total digestible nutrients required by cows on various rations.

DATES OF PERIODS	AGE AT STARTING	RATION	MILK YIELD	FAT YIELD	TOTAL DIGESTIBLE NUTRIENTS REQUIRED
Cow 71			*kgs.*	*kgs.*	*kgs.*
5/1/26 to 4/30/27	9 yrs., 10 mos.	Grain & alfalfa	4101	157	2844
10/1/27 to 9/30/28	11 yrs., 3 mos.	Grain & alfalfa	2055	77	2207
1/1/29 to 12/31/29	12 yrs., 6 mos.	Grain, alfalfa & timothy	3368	132	2594
Cow 84					
4/1/25 to 3/31/26	7 yrs., 6 mos.	Grain, alfalfa, & corn silage	2386	111	2248
12/1/26 to 11/30/27	9 yrs., 2 mos.	Grain, alfalfa, & corn silage	3633	164	2717
4/1/28 to 3/31/29	10 yrs., 6 mos.	Grain, alfalfa, & corn silage	3893	174	2801
11/1/29 to 10/31/30	12 yrs., 1 mo.	Grain, alfalfa, & corn silage	3435	153	2630
Cow 458					
4/1/27 to 3/31/28	5 yrs., 9 mos.	Grain, & alfalfa	4367	246	3157
7/1/28 to 6/30/29	7 yrs.	Grain & alfalfa	3849	215	2973
Cow 470					
1/1/26 to 12/31/26	4 yrs., 3 mos.	Grain & alfalfa	4281	252	3152
6/1/27 to 5/31/28	5 yrs., 8 mos.	Grain & alfalfa	4325	241	3117
11/1/28 to 10/31/29	7 yrs., 1 mo.	Grain, alfalfa, & timothy	4289	246	3169
3/1/30 to 2/28/31	8 yrs., 5 mos.	Grain, alfalfa & timothy	5422	304	3677
Cow 482					
1/1/25 to 12/31/25	2 yrs., 7 mos.	Grain, alfalfa, & corn silage	2434	150	2449
5/1/26 to 4/30/27	3 yrs., 11 mos.	Grain & alfalfa	2951	168	2708
10/1/27 to 9/30/28	5 yrs., 4 mos.	Grain, alfalfa & timothy	3812	216	3117
2/1/29 to 1/31/30	6 yrs., 8 mos.	Grain, alfalfa, & timothy	3445	193	2985

TABLE 5

Largest amounts of dry roughage eaten by cows in calendar months on different rations, and circumstances under which these record amounts of roughage were eaten

COW	DATE	RATION	GRAIN		TOTAL DRY ROUGHAGE[1]		MILK YIELD	CONSUMPTION[2] AS PER CENT OF REQUIREMENT[2]
			Offered	Eaten	Offered	Eaten		
			kgs.	kgs.	kgs.	kgs.	kgs.	
71	Oct., 1926	Grain & alfalfa	279	252	232	228	335	130.7
458	May, 1927	Grain & alfalfa	271	252	248	233	551	94.3
470	March, 1926	Grain & alfalfa	279	279	248	235	443	107.2
482	July, 1926	Grain & alfalfa	267	262	217	182	374	106.5
84	Jan., 1930	Grain, alfalfa & corn silage	248	245	282	279	423	126.7
482	March, 1925	Grain, alfalfa & corn silage	186	186	235	229	250	121.1
71	Feb., 1929	Grain, alfalfa & timothy	235	230	308	266	443	112.3
470	Dec., 1928	Grain, alfalfa & timothy	267	267	383	323	506	110.3
482	March, 1929	Grain, alfalfa & timothy	248	248	281	245	466	99.6

[1] When the cows were on alfalfa and corn silage the "Total Dry Roughage" eaten is calculated by adding the amount of hay eaten to the amount of silage multiplied by 0.263. This figure represents the dry matter in the silage.

[2] Of total digestible nutrients.

might reasonably be attributed to her age. She is still doing fairly well at the present time (March 4, 1931).

Cow 470 did about as well in her first lactation on the combined hays as in the two previous lactations on alfalfa as the sole roughage, in spite of the fact that she was quite sick at the beginning of the first mentioned lactation and began at this time to show some stiffness in her legs, possibly of a rheumatic nature. In her second lactation on the combined hays she has done much better than she ever did before and better than any of the Jersey cows in the group on these experiments. Her stiffness has become somewhat more marked and she has been kept in a box stall, while in the barn, in her 1930–31 lactation period. Experiments carried out at this station in 1922 and 1923, but still unpublished, have indicated that keeping cows in box-stalls instead of stanchions has a favorable influence on milk and fat yield amounting to less than 5 per cent. In the case of cow 470, it is doubtful whether the favorable influence of the box stall would have offset the unfavorable influence of her gradually increasing stiffness. She is still doing very well at the present time (March 4, 1931).

Cow 482 gave decidedly more milk and fat in the two lactations on the combined hays than in either of the two preceding lactations. She died on August 5, 1930, six months after the end of the second lactation on the combined hays and was found on post mortem examination to have a widespread inflammation of the intestines.

DISCUSSION

The foregoing results seem to indicate that cows do not eat at their best on rations in which either alfalfa or timothy hay is the sole roughage; that combining the two hays increases their appetite and particularly their willingness to eat large quantities of hay; and that the increased hay consumption on the combined roughage is likely to be accompanied by an increased milk and fat yield.

That cows receiving no hay except alfalfa develop a craving for other kinds of hay has been observed by Erf (2), and he states that adding blue grass or timothy hay of good quality to the rations of such cows increases their milk yield. He does not, however, give any figures to show either increased hay consumption or increased milk yield on the combined hays. A study has recently been made of the hay preference of about twenty-five milking cows in the Beltsville herd which had previously been on various rations—some on either alfalfa or timothy as the sole roughage, and some on alfalfa and corn silage. When offered both kinds of hay at the same time, the cows which had previously been on either as the sole roughage for any length of time almost always showed an unmistakable preference for the other. On the whole, there seems a great deal of reason to believe

that for some reason or other alfalfa and timothy hay combined make a more suitable roughage for dairy cows than either fed by itself.

In regard to the effects of the combined roughages on milk yield, on the other hand, a good deal of caution should be observed. The results so far obtained at Beltsville are based on work with only three cows. Further experiments designed to confirm or correct them are already under way.

In considering the nutritional background for the observations that have been made, it must be emphasized that the hay fed was all of good quality. The results furnish no guarantee that cows would eat large quantities of combined timothy and alfalfa hay of poor quality, or that the consumption of large quantities of poor hay would improve the milk yield. The effect of different qualities of hay on the appetite and milk yield of cows over long periods is a subject which is in great need of investigation. That hay, and particularly hay of good quality, supplies some unknown dietary essentials which are important in maintaining the health and milk yield of dairy cows has long been evident (1), (3), (4), (5), (7), (9), (10).

SUMMARY

Cows which are fed on grain with either timothy or alfalfa hay as the sole roughage are likely to consume rather small quantities of roughage and sometimes have periods of digestive disturbance and lack of appetite in which they show a very definite distaste for the kind of hay that they have had for some time past. Feeding the other kind of hay under such circumstances has often been followed by fairly rapid recovery from the digestive depression. The continued feeding of high-quality alfalfa and timothy together, under such circumstances that the cows could eat as much of each kind of hay as they wished, has resulted in a decidedly larger consumption of hay and in a larger milk yield than when alfalfa of good quality was the only kind of hay fed.

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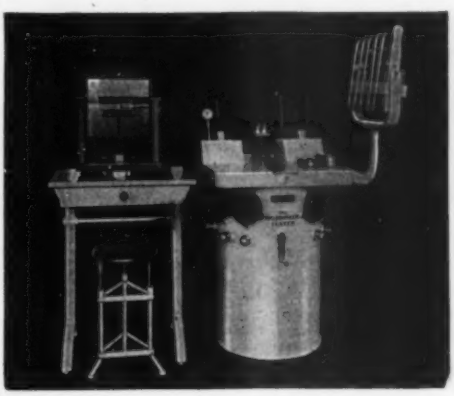

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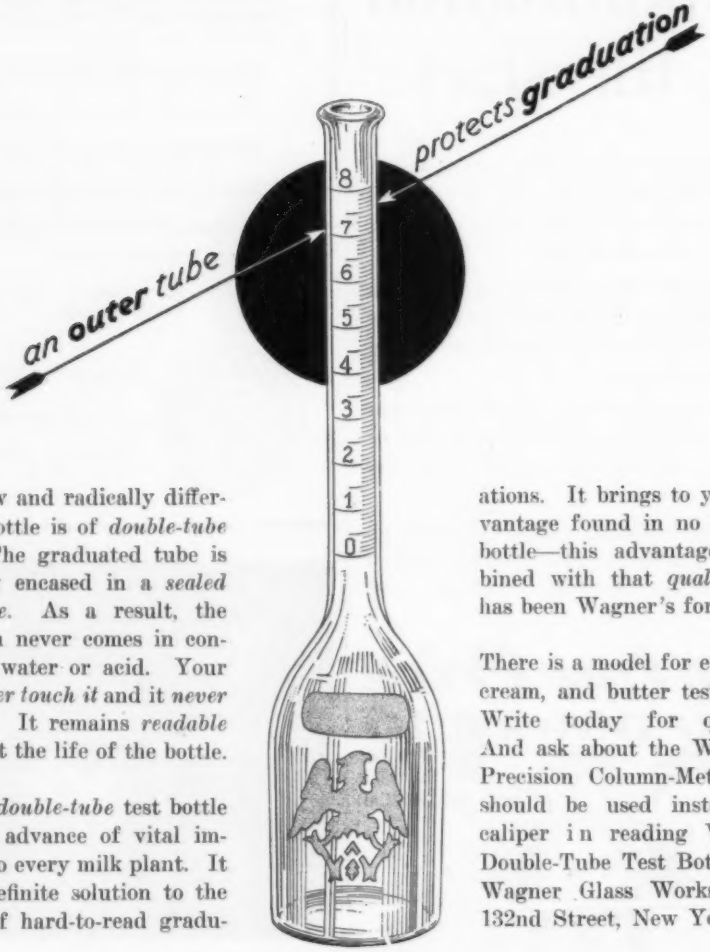

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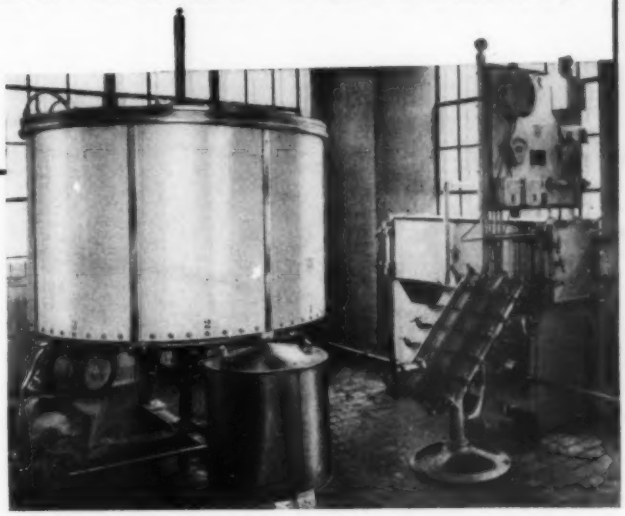

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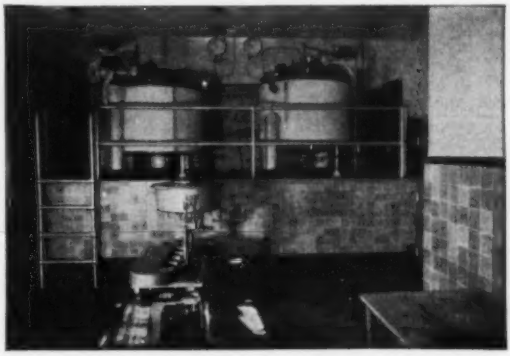

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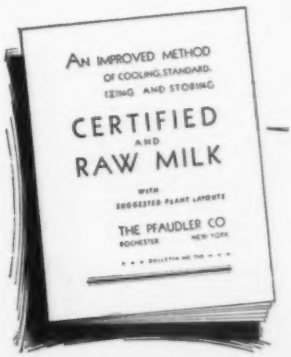

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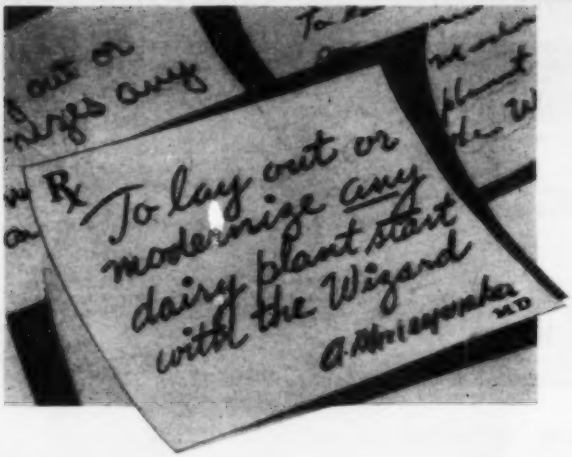

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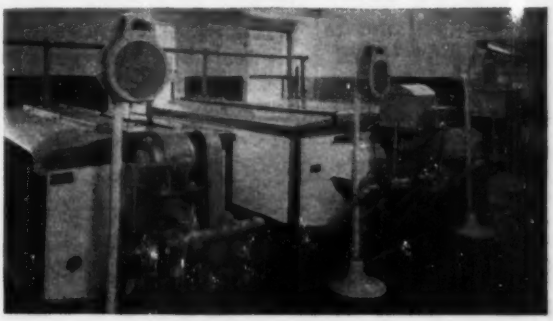

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